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INDIVIDUAL WATER SUPPLY SYSTEMS

Public Health Service
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Individual Water Supply Systems

RECOMMENDATIONS OF THE JOINT COMMITTEE ON RURAL SANITATION

Revised 1950

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FEDERAL SECURITY AGENCY • PUBLIC HEALTH SERVICE

68

Individual Water Supply Systems

Recommendations of the Joint Committee on Rural Sanitation

Revised 1950

FEDERAL SECURITY AGENCY • Public Health Service
Division of Sanitation of the Bureau of State Services

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Introduction

The development of safe and adequate supplies of drinking water for individual homes is essential and necessary to protect the health of the individuals residing in suburban areas. Urban fringe areas are often beyond the reach of municipal water systems, and individual wells or a community distribution system must be provided to serve these properties with a safe supply of water. The accelerated rate of housing construction has greatly aggravated environmental health problems, especially in fringe areas and rural communities.

The recommendations of the Joint Committee have been prepared primarily for the purpose of establishing a uniform approach for various Federal agencies concerned with the sanitation of individual water supplies. In addition, to insure a high degree of sanitary security, it is hoped that the recommendations will be useful to State and local health authorities, well drillers, and others concerned with the development and operation of such supplies. The recommendations are applicable to (a) all newly developed supplies, (b) alterations or extensions to existing supplies to eliminate sanitary defects, and (c) maintenance of special vigilance on all questionable conditions found in existing systems until adequate sanitation corrections have been made.

These recommendations are limited to the sanitation aspects of small water supplies used by one or possibly several families and by rural schools, recreational areas, camps, and similar developments which are without access to public water-supply systems. Because of the better public health control usually given to those public water supplies which are owned or directly controlled by a governmental organization, their use is recommended wherever practicable.

The Committee, in the preparation of this report, has drawn freely upon the experience of competent authorities, including many State sanitary engineers and the engineers and sanitarians engaged in city and county public health work. These authorities are concerned with water-supply sanitation problems in the various sections of the United States, and their experience embraces a wide range of hydrological, geological, and economic conditions. The illustrations shown in figures 1 to 11 have been adapted from publications of State and Federal agencies. Revisions have been made, where necessary, in order to incorporate the views of the Committee.

Persons engaged in developing water supplies should obtain the advice and cooperative assistance of the State sanitary engineering department concerned in order to determine compliance with existing regulations and requirements. In the absence of more rigid State or local governmental requirements, the recommendations of this report are offered as a guide.

MEMBERSHIP OF JOINT COMMITTEE

In June 1941, at the suggestion of various Government agencies interested in proper disposal of sewage and development of safe water-supplies in rural areas, the Public Health Service sponsored the appointment of a Joint Committee to study the problems involved and develop a set of uniform recommendations to be followed by the agencies concerned. The Joint Committee on Rural Sanitation now consists of the following representatives:

Chairman, C. H. Atkins, Chief, Division of Sanitation, Public Health Service.

Secretary, John B. Thomas, Division of Sanitation, Public Health Service.

United States Department of Agriculture:
- Office of the Secretary:
  - George R. Phillips.
- Bureau of Plant Industry, Soils, and Agricultural Engineering:
  - Harry L. Garver, Sr., Agricultural Engineer.
- Extension Service:
  - S. P. Lyle, in Charge of Agricultural and Home Economics Section.
- Farmers Home Administration (formerly Farm Security Administration):
  - Carl A. Johnson, Agricultural Engineer.
- Forest Service:
  - Clifford A. Betts, Construction and Hydraulic Engineer.
- Production and Marketing Administration:
  - H. M. Bowman, Industrial Specialist.
- Rural Electrification Administration:
  - E. L. Arnold, Power Utilization Specialist.
- Soil Conservation Service:
  - George W. Musgrave, Research Specialist.

*Conference of Municipal Public Health Engineers:
- William H. Cary, Jr., Director, Public Health Engineering, D. C. Health Department.

Conference of State Sanitary Engineers:
- C. H. Atkins, Sanitary Engineer Director, Secretary of Conference.

Federal Security Agency:
- Office of Education:
  - Dr. Ray L. Hamon, Chief, School Housing Section.
- Public Health Service:
  - Leonard M. Board, Sr., Sanitary Engineer.
  - S. R. Weibel, Sanitary Engineer.

Housing and Home Finance Agency:
- Office of the Administrator:
  - Laurence M. Shuman, Chief, Mechanical Engineering Section.
- Federal Housing Administration:
  - James R. Simpson, Sanitary Engineer, Underwriting Division.

Tennessee Valley Authority:
- Robert N. Clark, Chief Public Health Engineer.

United States Department of the Interior:
- Geological Survey:
  - A. G. Fiedler, Assistant Chief, Ground Water Division.

*Veterans Housing Administration:
- Loan Guaranty Service:
  - William B. Mason, Jr.

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*Became members March 1949.

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I.

Basic Requirements

QUALITY

The planning of a water-supply development or improvement requires a determination of the source or sources of water that are available and the quantity and quality of the water that may be obtained from available sources. A general knowledge of the hydrological, geological, and bacteriological factors affecting the quantity and quality of water available is essential for a proper evaluation of the possible sources of supply.

When rain falls or snow melts, the water seeps into the soil at a rate depending on the capacity of the soil to transmit water and upon its dryness and other factors. This process is called infiltration or seepage. If the rainfall is heavy or the snow melts rapidly, only a part can seep into the soil. The rest runs off the surface and is drained away by the creeks and rivers. Part of the soil moisture is returned to the atmosphere either by direct evaporation or by the transpiration of plants. The remainder of the soil moisture seeps into subsurface formations, thereby replenishing the ground-water supply. In times of heavy infiltration, more water may seep into the soil than the soil can hold against the pull of gravity. A part of the water therefore moves downward through the underlying subsoil and rocks until it reaches the level of the completely saturated formation which is known as the water table. This process (called ground-water recharge) may occur in all seasons but takes place chiefly in winter and early spring when there is little evaporation or transpiration. In cold climates, the principal recharge may occur in spring when the frost leaves the soil.

The nature of the earth formation in any vicinity affects not only the quantity of water that may be recovered but also its mineral characteristics. When water from rain or snow runs over the land surface, it picks up particles of soil which produce the turbidity of streams; it also picks up filth of various kinds which has been deposited on the surface, including great numbers of bacteria, most of which are harmless. When sur-

face water seeps downward into the soil and then through the underlying material to the water table, most of the particles held in suspension are filtered out so that the water recovered from wells and springs is generally clear. This natural process of filtration is very effective in removing bacteria from the surface water as it passes through the soil to become ground water. However, because certain soils and rocks contain soluble minerals, ground water frequently contains more dissolved minerals than surface water. These mineral substances are objectionable if dissolved in large quantities, and some are toxic or poisonous even in small amounts. Practically all waters contain measurable quantities of silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride; nitrate and other forms of nitrogen are sometimes present in considerable quantities in ground waters.

Bicarbonates of calcium, magnesium, iron, and manganese are dissolved by water that has lost oxygen to organic matter near the surface and has built up a high content of carbon dioxide. Hard water usually contains bicarbonates of calcium and magnesium and may contain large amounts of sulfates and chlorides. Hardness is objectionable for laundry and other washing purposes because soap consumption is increased. Heavy concentrations of soap in laundering result in a deterioration of fabrics. In steam boilers, the scale resulting from hardness reduces thermal efficiency by insulating pipes.

The occurrence of harmful inorganic substances in water is not common. Certain substances, however, do occasionally occur in natural waters which are dangerous even in small concentrations. Arsenic, selenium, vanadium, and lead may be found in water in regions where deposits of ores of these elements occur. Occasionally industrial wastes containing these elements are discharged to streams which may be used as sources of drinking water. High chlorides indicate a possible pollution with sewage particularly if the normal chloride (that present in the absence of pollution) is known. Urine contains about 6000 ppm of chlorides. Chloride concentrations above 250 ppm produce a disagreeable taste. Fluorides occur naturally in certain waters, generally in ground waters. Fluorides in excess of approximately 1.5 ppm cause mottling of the enamel of teeth. Boron, while not particularly harmful to people, damages certain crops, specifically the citrus fruits. Lead, copper, and zinc may occur in water as a result of corrosive action of the water on distribution piping made of, or coated with, these metals. Nitrate nitrogen is reported to be the cause of methemoglobinemia (infant cyanosis) in infants. Where found in high concentrations, generally in shallow wells, it is an indicator of surface pollution. When the presence of nitrate nitrogen is suspected, the advice of local health authorities should be solicited. The following substances, due to their toxicity,

should be guarded against in the concentrations exceeding those listed below.

Substance	*ppm*
Arsenic	0. 05
Selenium	0. 05
Lead	0. 1
Fluorides	1. 5
Vanadium	1. 0
Boron	1. 0
Copper	3. 0
Zinc	15. 0

Water for drinking and culinary purposes must be free from pathogenic bacteria, protozoa, and other disease-producing organisms, as well as from physiologically harmful chemical or mineral substances. Clearness, softness, freedom from objectionable taste and odor, and low temperature are desirable. Green water is sometimes produced when exceptionally corrosive water comes in contact with copper piping. Where such water exists these conditions should be guarded against in order that the copper content does not exceed that stated in the above table.

Turbidity is objectionable not only because it makes the water less attractive for drinking, but because it frequently indicates inadequate protection from surface wash and possible bacterial contamination.

Brownish or reddish color which remains in solution or in colloidal dispersion, even after the turbidity caused by suspended soil particles has settled out, may result from surface water contact with peat, humus, or decomposing organic matter such as is found in spruce or hemlock forests.

Algae and aquatic micro-organisms are chiefly objectionable because of the offensive odors and tastes they impart to water. Discoloration in water may also result from the presence of these organisms.

Most surface supplies and some ground waters require treatment before they are suitable for domestic use, and all sources should be under suspicion until standard tests prove that they are adequately protected from contamination.

Selection of the water supply having the best quality and the protection of this supply from contamination are prime considerations in attaining suitable quality with a minimum of treatment. To this end, sanitary surveys aid greatly in assuring a satisfactory water supply. The bacteriological and chemical quality of the supply should conform to the requirements and recommendations of the Public Health Service Drinking Water Standards.[1]

[1] Reprint No. 2697 from the Public Health Reports, available through the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 5 cents per copy.

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ANALYSES

Bacteriological analyses show the presence or absence of contamination in the collected sample only. They therefore serve merely as an indication of the safety of the water supply at the time collected and, hence, should be used only to supplement the information obtained from a sanitary survey of the water source, appurtenances, and surroundings. Sole reliance in determining the safety of water supplies cannot be placed on the results of infrequent bacteriological analyses; supplies which are potentially hazardous may be erroneously judged to be safe if contamination is not present at the time the samples are collected, although there may be faulty location, construction, or operation of the supply. Periodic examinations will provide better control in such cases.

It is desirable that the person who makes the field investigation of the water supply also collect the samples for bacteriological analysis and interpret the analytical results. Special precautions are necessary in collecting the samples, and training and experience are also necessary in interpreting and evaluating the results. Therefore, the assistance of local or State health authorities should be requested if there is any question concerning the safety of a supply.

Frequently, the bacteriological examination of a sample of water collected prior to disinfection of a well which has been recently constructed or repaired will show contamination. This is usually because surface contamination is carried into the ground water or well during construction or repair and does not mean that the ground water was contaminated before the well was constructed or repaired. If a well is properly located and constructed, the water usually will be bacteriologically satisfactory after the well has been completed and disinfected. Samples of newly developed wells or wells which have been repaired should not be taken for bacteriological analysis until after completion and disinfection of the well. The advice of the local or State health department should be obtained before collection of the sample for examination because such samples must be collected in sterile bottles.

The chemical characteristics of ground water in a particular locality will ordinarily be known as a result of experience with other wells in the vicinity drawing from the same stratum. However, there are commercial laboratories in most large cities which can make and interpret a chemical water analysis, and some State health departments and State colleges can undertake the chemical analysis of a limited number of samples of private water supplies. Ordinarily a chemical analysis of a domestic supply will include: total hardness, alkalinity, pH, sulfates, and chlorides. Determination of nitrate nitrogen content should also be made. Iron, manganese, and fluoride may also be determined in some cases. A gallon sample is usually sufficient, but it is best to find

out from the laboratory which will conduct the analysis the amount of sample required and the preferred method of collecting it.

QUANTITY

The quantity of water required will vary with individuals and with local conditions. The installation of modern plumbing greatly increases water usage over the amounts used when water has to be hand-pumped and carried. The availability of water under pressure stimulates its use in the sprinkling of lawns and gardens, for the washing of automotive equipment, and for various purposes at farms, camps, and schools. Since the water requirements will influence practically all other features of development or improvement, they should be given careful consideration before plans are made.

The following figures may be used as a guide in preparing estimates, although local adaptations may be necessary:

	Normal gallons per day
Domestic use (per person):	
Household having—	
1 hand pump	10
1 pressure faucet at kitchen sink	15
Hot and cold running water—	
Kitchen, laundry, and bath	50

	Gallons per day
Camps and schools (per person):	
Work camp with hot and cold running water—	
Kitchen, laundry, shower bath, and flush toilets	45
Camp with flush toilets	25
Camp without running water or flush toilets	5
Day schools	17

	Gallons per day
Livestock:	
Per horse, mule, or steer	12
Per dairy cow (drinking only)	15
Per dairy cow (drinking and dairy servicing)	35
Per hog	4
Per sheep	2
Per 100 chickens	4
Per 100 turkeys	7

	Gallons per hour
Garden, fire, and other uses:	
Garden hose, ⅝-inch	200
Garden hose, ¾-inch, ¼-inch nozzle	300
Fire hose, 1½-inch, ½-inch nozzle	2,400
Continuous flowing drinking fountain	75

The estimation of stock water requirements must be taken into consideration, because inadequacy of meeting the total requirement will inevitably affect the quantity and possibly the quality of the supply available for domestic use. In some instances, the requirement of water for fire-fighting and irrigation purposes also should be considered, although the amounts needed will vary widely in accordance with the type of project for which the water supply is being provided.

II.

Ground Water

ELEMENTS OF GROUND-WATER GEOLOGY

Rock Formations in Relation to Their Water-Bearing Properties

The rocks that form the crust of the earth are divided into three classes: igneous, sedimentary, and metamorphic. The igneous rocks are derived from the hot magma that occurs deep in the earth. They include granite and other coarsely crystalline rocks; dense igneous rocks such as occur in dikes and sills, basalt and other lava rocks; and cinders, tuff, and other fragmental volcanic materials. The sedimentary rocks consist of rock fragments deposited by water, ice, or wind, and chemical precipitates. They include deposits of gravel, sand, silt, and clay, and the hardened equivalents of these, namely, conglomerate, sandstone, siltstone, and shale; also limestone and deposits of gypsum and salt. The metamorphic rocks are derived from the igneous and sedimentary rocks through profound alteration by heat and pressure at great depths. They include gneiss, schist, quartzite, slate, and marble.

The openings in rocks, which may serve as reservoirs or conduits of the ground water, are of three general classes: the interstices that occur between the rock particles, as in deposits of sand and gravel; the cracks and fissures, generally called joints, by which the hard rocks are broken; and the crevices and caverns such as are formed by solution in limestone and by other processes in lava rocks.

The rocks below the water table are said to be in the zone of saturation because in this zone the pores, joints, and crevices in the rocks are generally full of water. Although the openings in the rocks are usually small, the aggregate quantity of water that is stored in the subterranean reservoirs of the rock formations is very great. The water in the zone of saturation is called ground water.

A rock formation that will yield water to springs or wells is called an aquifer. Where an aquifer has a water table it is said to have phreatic or "water table" conditions; where its water is confined under

an overlying bed that is relatively impermeable it is said to have piestic or "artesian" conditions.

The character of a rock formation with respect to water supply depends chiefly on its porosity, specific yield, and permeability. The porosity of a rock is the proportion of its volume that consists of open spaces, which obviously determines the capacity of the rock to store water. The specific yield of a rock is the quantity of water that it will yield in proportion to its volume. The specific yield of any rock is less than its porosity because some of the stored water is held by the molecular attraction of the rock. In rock formations having large openings, such as clean gravel, the specific yield is not much less than the porosity and nearly all the stored water is free to flow into the wells or springs; but in formations having very small openings, such as silt or clay, the specific yield may be very small even though the porosity is large or all the water may be in dead storage and the specific yield may accordingly be zero.

The permeability of a rock, or its capacity to transmit water or any other fluid, depends not only on its porosity but also on the size and interconnection of its openings. Thus clean gravel and coarse, clean sand have large permeability, whereas fine sand, silt, clay, and sand or gravel whose interstices are filled with silt or clay have small permeability even though their porosity may be large.

The most productive aquifers are the deposits of clean, coarse sand and gravel, the coarse porous sandstones, the cavernous limestones, and the broken lava rocks. Some limestones, however, are very dense and unproductive. Most of the igneous and metamorphic rocks are hard and dense and have low specific yield and low permeability. They generally yield small supplies of water, but the water comes from the cracks and fissures or from the interstices in their surficial weathered parts. Among the most unproductive materials are the silts and clays which have interstices that are too small to yield water and which are too incoherent to maintain large openings under much pressure. However, silty and clayey materials near the surface are less compact and may yield small supplies.

Movement of Ground Water

Where water from the surface seeps down to the zone of saturation, the water table tends to be built up. On the other hand, in low places in which ground water is discharged through springs or by evaporation and transpiration, the water table is depressed. Thus the water table is not a level surface but slopes gently from intake areas toward areas of ground-water discharge. Although the depth to the water table is generally greater on high land than on adjacent low land, the

water table, nevertheless, generally slopes toward the low land where the discharge occurs.

The ground water is not generally stationary but moves slowly from places of high elevation to places of lower elevation. Its movement is indicated by the hydraulic gradient, which in the upper part of the zone of saturation is in the direction of the slope of the water table. Therefore, sanitary security requires that sources of possible contamination be removed from land that slopes toward the well or spring, or, alternatively, that a well be constructed or a spring be found in a location where the higher land is free from possible sources of contamination. This rule applies especially to wells under "water table" conditions, in contrast to those under "artesian" conditions, as is explained in the next section.

The rate at which the ground water moves is determined by the permeability of the water-bearing material and the hydraulic gradient. There is a great range in both of these factors among the different water-bearing materials and from place to place, and, hence, a still greater range in the natural rate of movement of the ground water. The natural rate of movement in formations that supply wells is generally not more than a few feet a day and may be only a few feet a year. It may, however, be rapid in large joints or fissures in the hard rocks and especially in the subterranean drainage systems in cavernous limestone.

Rock Structure in Relation to Contamination

Sand and other fine-grained materials are generally effective in filtering out the bacteria contained in the water. However, formations such as coarse gravel, cavernous limestone, and broken lava rocks have such large openings that they are not effective as filters.

The sedimentary rocks were largely deposited in successive layers or strata. The strata may differ greatly in permeability. Thus, in many places the drill passes through successive layers of relatively impermeable clay interbedded with strata of water-bearing sand or gravel. An aquifer that is overlaid by an impermeable bed is not recharged through the overlying bed but by lateral percolation from a locality where the overlying bed is absent or has changed its character so that it permits the passage of water through it. The intake area may be relatively near, as in some places in alluvial deposits, or many miles distant, as in systems of extensive and relatively uniform rock strata. The water in aquifers underlying impermeable or nearly impermeable beds is generally free of disease-producing bacteria. An exception to this general statement would be water drawn from solution channels in limestone that underlie an impermeable bed broken by sinkholes. Where an aquifer is overlaid by an impermeable or nearly impermeable bed, a large degree of sanitary security can be obtained by drilling through this bed and into

the aquifer and providing the well with durable watertight casing that extends into or through the relatively impermeable bed, where it should be tightly sealed. However, even under such favorable conditions, the measures for sanitary quality should be applied, especially because the casing or installation might be defective, or openings might develop in the casing by wear or corrosion, and ground water overlying the impermeable bed might thus get into the well.

The water in an aquifer that is overlaid by a relatively impermeable bed is generally, though not everywhere, under sufficient head to rise above the bottom of the impermeable bed. The impermeable bed is then called a confining bed and the water is called piestic, or artesian water. When a well that draws from an artesian aquifer is pumped, a cone of depression is developed that is due to a lowering of the head, generally without unwatering any of the aquifer.

In most places there is also ground water with a water table above the confining bed. If the head of the artesian water is sufficient to cause it to rise in the well above the water table, any movement of water that may occur through the confining bed or around the well casing will be upward, thus preventing local contamination. However, when the well is pumped the head in the artesian aquifer may be lowered sufficiently so that any movement will be downward and local contamination might occur.

If the head of the artesian water is sufficient to rise in the well above the surface, the well will discharge water without pumping and is called a flowing well. The term "artesian" was first applied to wells of this kind. A flowing well affords a high degree of sanitary security because the pressure in the aquifer and in the well is everywhere outward, which prevents the entrance of contaminated water.

Types of Springs in Relation to Contamination

Springs may be divided, according to their mode of origin, into gravity and artesian springs.

Gravity springs may be formed where water percolating laterally through permeable material overlying an impermeable stratum comes to the surface. Gravity springs also may be formed where there is no outcrop of an impermeable stratum but where the land surface intersects the water table. This type of spring frequently dwindles to a seep in dry periods.

Artesian springs are those in which water is confined below impermeable beds and is under hydrostatic pressure because the source of the water is at a higher elevation than the spring. Artesian springs are less likely to be contaminated than gravity springs.

Springs may be further classified, according to the nature of the passages traversed by the water, into seepage, tubular, and fissure springs.

Seepage springs are those in which the water seeps out of sand, gravel, or other material that contains many small water-bearing interstices. The term as here used is not confined to small springs but includes many large springs, some of them with extensive seepage areas. Such springs are usually marked by abundant vegetation. The water of small seepage springs may be colored or may carry an oily scum due to the decomposition of organic matter or the presence of iron. Seepage springs may emerge along the top of an impermeable bed, but more commonly they occur where valleys are cut into the zone of saturation of more or less uniform water-bearing deposits. Their water is generally free of harmful bacteria unless there are nearby sources of contamination.

Tubular springs issue from relatively large and more or less tubular channels such as the solution channels and caverns of limestone and other soluble rocks, and also smaller channels that occur in glacial drift. They are said to be bold springs because the water issues freely from one or more large openings. If the water reaches the channels by percolation through sand or other fine-grained material it is usually free from contamination, but if the channels receive surface water directly, or the effluent of cesspools or privies, the water they discharge must be regarded as unsafe.

Fissure springs issue along bedding, joint, cleavage, or fault planes. Their distinguishing feature is a break in the rocks along which the water passes. Some of these springs discharge uncontaminated water of deep-seated origin. A large proportion of the thermal springs are of this type. Many of the fissure springs, however, discharge water that has not been far below the surface and which, therefore, may be contaminated from surficial sources.

Usually the contamination of springs occurs where barnyards, sewers, cesspools, or other sources of contamination are located on higher land near the springs. In limestones, however, sewage or other polluting matter frequently enters the water-bearing channels through sinks or other large openings, and may be carried along with the ground water for long distances. Similarly, if material from a cesspool or other source of contamination finds access to the tubular channels in the glacial drift, the water may retain its contamination for long periods and relatively great distances.

Sanitary Quality of Ground Water

Water on the surface in the vicinity of human habitation is usually contaminated by the presence of bacteria that normally inhabit the intestinal tract of warm-blooded animals, including man. These organisms, members of the coliform group of bacteria, may not be injurious themselves, but they give warning that the water is contaminated with excreta which may be of human origin. The dangerous bacteria

are chiefly those from the sewage wastes of persons who have typhoid or other enteric (intestinal) diseases or who still carry the bacteria of these diseases after they have recovered.

When surface water seeps downward into the soil and thence through the underlying material to the water table, the particles that it holds in suspension, including bacteria, are filtered out to a degree depending on the depth and character of the material overlying the water table. In addition, the bacterial quality of ground water may be expected to improve due to the time of storage in the water-bearing formation under conditions that are not suitable for the maintenance of bacterial life.

Bacteria are extremely small, much smaller than most of the suspended particles that make water turbid. They are smaller than the interstices in most soils and sands, and under certain conditions they may be carried by the water as it percolates through the overlying formations. Consequently, ground water may be clarified yet contain an objectionable and dangerous concentration of bacteria.

In the recovery of ground water it is well to remember that bacteria carried downward by the water reach first the top of the zone of saturation, or water table, and that they are not likely to penetrate far below that level. Dug and bored wells that extend only a short distance below the water table are likely to admit water that has had a minimum of storage time in the water formation and, consequently, is more apt still to retain contaminating bacteria. A greater degree of security from contamination can be obtained by constructing a well with a watertight casing that extends a considerable distance below the normal water table.

The most effective protection of ground water is afforded by impermeable strata of clay, hardpan, etc., which may separate portions of the topsoil and water-bearing sand and gravel to which the well penetrates. In the absence of overlying impermeable strata, maximum protection is afforded the quality of ground water when the overlying formations are of a sandy character and of sufficient depth to insure good filtering action. Minimum protection is afforded when the surface water may reach the water table through relatively large openings formed in the soil and subsoil by animal burrows, tree and plant roots, cracks in soil or rocks, solution channels in limestone rock, coarse gravel formations, or man-made excavations.

In rural areas and in villages without sewer systems, the human excreta are deposited largely in pit privies or in cesspools or septic tanks, but some are deposited in the barnyards and mingled with the excreta of domestic animals. The bacteria in the excreta in privies, cesspools, and septic tanks may have a better chance to reach the water table than those at the surface because these excavations or their effluent structures may

extend close to, or even into, the zone of saturation. Moreover, the large quantities of liquid discharged through the cesspools and septic tanks help to carry the bacteria down to the ground water. In some places the ground water is contaminated directly by draining sewage or other waste into abandoned wells or wells drilled for that purpose, a practice that should be generally condemned.

Relative security from contamination can be obtained by removing the possible sources of contamination as far as practicable from the well or spring or alternatively by constructing a new well or developing a new spring as far as practicable from the possible sources of contamination. Unfortunately, on most farms the well and also the barnyard and privy or sewerage facilities are relatively near the house, a condition that is conducive to contamination of the water supply. If a pressure water system is installed, there is no longer need for having the well near the house, and in many cases the sanitary situation can be improved by drilling a new well farther from the house and from the possible sources of contamination. In villages the homes are so close to each other that the only satisfactory solution of the sanitary problem may be to install public waterworks and, if practicable, also sewer systems.

Ground water obtained from properly located and constructed wells is generally pure in the sense that it is free from disease-producing bacteria. It was the principal source of safe water supplies before the processes of artificial purification were understood, and it is still the source of many public water supplies and several million private water supplies in this country.

SANITARY RECOVERY OF GROUND WATER

The numerous ways by which surface water may reach the ground water without adequate purification, or in which the ground water may later become contaminated, have been pointed out in the earlier portions of this section.

All wells should be so located as to obtain ground water that has had the maximum protection that can be provided by the local geological formation, surface topography, and land usage. Wells should be constructed to exclude surface water and ground water infiltration above the level of the water-producing formation. A properly constructed well should be as effective in excluding surface water as was the undisturbed overlying geological formation.

Exclusion of Surface Water From the Well Site

The site within a safe horizontal distance of the well in all directions should not be subject to flooding and should be graded and drained

to facilitate the rapid removal of surface water. To assure reasonable protection against entry of surface water, the following precautions should be taken:

The earth surface should be sloped from the well so as to divert surface water away from it. The surface should be graded and maintained so as to prevent the accumulation and retention of surface water within a distance of 50 feet from the well in all directions. Pump platform, pump-room floor, or covers of a ground-water supply should be located not less than 2 feet above the highest known high-water level of any nearby body of surface water. The area around the well should be filled and graded to the necessary height: the fill may be protected from erosion by riprap or sod where necessary. Flood waters from nearby bodies of surface water should not be allowed to approach within 50 feet of the well.

For a well on a hillside an adequate intercepting ditch or ditches should be constructed on the uphill side of the well in such manner as to keep the storm water at least 50 feet away from the well in all directions. These ditches should have capacity to carry the runoff of heavy storms and should be maintained adequately. Wells should not be located in ravines where storm waters can get close to them.

Locating a well beneath a house has the disadvantages of making it difficult to prevent contamination, to repair and maintain the well and equipment, and to keep the basement dry and clean.

Distances to Sources of Contamination

All ground-water sources should be located a safe distance from sources of contamination. A safe distance is dependent upon numerous local factors and its determination involves, among other things, the evaluation of the following: character and location of the source of contamination, type of well construction, natural hydraulic gradient of the water table, permeability of the water-bearing formation, extent of the cone of the depression formed in the water table due to pumping the well, and the type of rock structure.

Because the determination of a safe distance between a ground-water source and a source of contamination is dependent on many factors, it is impracticable to establish arbitrary distances which will be adequate under all conditions. Each installation should be inspected by a person with sufficient training and experience to evaluate all of the factors involved. However, there are not enough trained individuals to provide the service for all installations and many of the Federal and State agencies are confronted with the problem of making recommendations or establishing requirements. Therefore, to meet the problems in a practical manner this Committee, in its recommendations, "Individual Sewage Disposal Systems," specified certain minimum distances. These distances were determined after consideration of the available information and are as follows: pit privies, septic tanks, sewers, and subsurface pits, 50 feet; seepage pits, subsurface sewage disposal fields, and barnyards, 100 feet; and cesspools, 150 feet. In addition to the above minimum distances, where the area adjacent to the water source is accessible to livestock the site should be enclosed by a fence located

in all directions not less than 100 feet from the water source. Where drainage from barnyards or other areas used by livestock may reach the water source because of local topography or soil formation, a greater separation than 100 feet should be provided. All of the above are minimum distances and may be inadequate when all conditions are not favorable as in the case of creviced earth formations or very permeable soil. Requirements of the State health department concerned should be ascertained and observed.

So far as practicable, a well should not be located on the side of or at the foot of a hill if cesspools, privies, sewers, or other sources of contamination are situated where they would be above the well and in the path of the ground-water flow toward the well.

Some work has been done to measure and study the subsurface movement of contamination. References to these studies are given in the bibliography. However, there is great need for additional research on this problem.

The information available indicates that contamination discharged below the land surface, as with a privy, cesspool, or septic-tank disposal field, seeps almost vertically downward until it reaches the water table. It then tends to float out into the upper blanket of the ground water close to the water table and to travel in the direction of the ground-water flow. Consequently, contaminated ground water, in its normal path of flow, may move toward a well.

While water is being pumped from a well, the water in the well declines, and under water-table conditions the water table in the vicinity of the well also declines. Thus, a so-called cone of depression or zone of influence is formed in the water table, and within it the water table slopes toward the well from all directions. This depression of the water table alters the normal ground-water flow and may permit contaminated ground water to travel toward a well not in its normal path of flow.

The steepness of the cone of depression influences the rate at which the water is drawn toward the well. In approaching a well that supplies water, the slope of the water table and, hence, the velocity of the ground water becomes progressively greater until the intake of the well is reached. The area from which a well may draw contaminated water during pumping operations and the rate at which the water will be drawn to the well increase with the rate of pumping. Therefore, other things being equal, the danger of contamination is increased when the pumping of a well is increased, as, for example, to serve several homes instead of one.

Conversely, the effluent from a septic tank, as it seeps down to the zone of saturation, will build up a larger and higher mound in the water table than is built by the comparatively small amount of seepage from a pit privy. Hence, effluent from a septic tank may reach a well

even though seepage from a privy located near the same place does not. When an individual water supply is installed, careful consideration should be given to these two increased chances of contamination. The septic-tank system should be located a safe distance from, and on the downhill side of, the well site. Where high ground water or exceptional soil conditions are encountered, the advice of the local health department should be obtained.

Types of Wells

Water wells necessarily extend into the zone of saturation, and they may extend to aquifers at great depths. With respect to methods of construction, wells may be classified into four groups: (1) dug, (2) bored, (3) driven, and (4) drilled.

A dug well is constructed by excavating a shaft, generally by means of hand tools, and installing casing where needed. Dug wells are used extensively for domestic water supplies. They are generally not very deep, as they cannot readily be sunk far below the water table or far into solid rock. Most of them are less than 50 feet in depth. They generally yield only small supplies from water-bearing materials of rather low permeability near the top of the zone of saturation. They are necessarily relatively large in cross section and have correspondingly large storage capacity for each foot that they extend below the water table. However, because of their shallow penetration into the zone of saturation, many dug wells fail in times of drought when the water table recedes.

A bored well is constructed by boring a hole with a hand- or machine-driven auger, and installing tile or other casing. Bored wells range in diameter from only a few inches, where hand-operated augers are used, to as much as a few feet where machine-driven augers are used. Like dug wells, they do not extend into the hard rocks and most of them are not sunk far into the zone of saturation. Accordingly, to a great extent, they resemble the dug wells in generally having relatively small yields and in being affected by droughts.

A driven well is constructed by driving a pipe, usually fitted with a well point and screen, with the aid of a maul, drive donkey, or pile driver. Driven wells are confined to localities where water-bearing sand or fine gravel lies at comparatively shallow depths and where there are no intervening hard rocks or boulders that would prevent driving the pipe. Under these conditions, driven wells can be constructed rapidly and at small cost. The pipes used are of different sizes but are commonly 2 inches or less in diameter. These wells are usually pumped by suction with pumps fastened to the tops of the pipes. Wells of this type are likely to be impracticable if the sand or gravel has low permeability, but if the permeability is high they may yield copiously.

A drilled well is constructed by making a hole with a drilling machine of any type and installing casing and screen where needed. The excavating may be done by percussion or rotary tools or by jetting, and the materials may be brought up by means of a bailer or hollow drill tool or by a hydraulic process, in which water or mud-laden fluid is pumped down the hole and carries up the excavated material as it returns to the surface. Drilling methods have a great advantage over digging, boring, and driving methods, in that they are adapted for sinking the holes to aquifers that may lie far below the water table. Drilled wells, therefore, tap water supplies that may not be recoverable with wells of other types, and as a rule they have larger yields and are less affected by drought. To a large extent, they are gradually replacing the dug and bored wells. The different kinds of drilled wells range widely in diameter, up to 2 feet or more. Many of the domestic wells drilled with percussion rigs are about 6 inches in diameter, and most of the jetted wells are between 1 and 3 inches in diameter. Domestic wells of good construction in unconsolidated materials are generally finished with standard wrought-iron or steel well casing having screw joints and with durable sand screens of proper mesh. Gravel packing may increase the yield.

Infiltration Galleries

Where no other supply is available, it may be feasible to construct infiltration galleries in a stream bed or a short distance back from the bank where water may be collected in open-joint pipe.

The supply for such galleries, as well as for shallow wells, can be augmented by driving sheet piling as a subsurface dam to hold back the ground water.

Susceptibility to contamination is a limiting factor in the use of these expedients. Galleries, therefore, should not be placed where the filtering value of the soil is insufficient to insure a safe supply.

Well-Construction Details

Casings. Wells are cased to keep the hole open in formations likely to cave, to exclude contaminated surface water and rodents, and to seal off undesired water-bearing strata. In wells of all types, the casing should extend at least 6 inches above the graded-up land surface at the well.

The following information concerning casings applies to specific types of wells.

Drilled and driven wells. A drilled well should be cased with new standard wrought-iron or steel well casing or with other casing that is at least equally watertight and durable (fig. 1). The sections should be joined together by threaded couplings or by welding so that the joints will be watertight. So-called stovepipe or sheet-metal casing is not satisfactory.

To exclude surface water and water from undesirable strata from drilled wells, the casing should be carried where possible through an impermeable stratum above the water-bearing stratum, and a tight seal should be made between this impermeable stratum and the casing. Where no impermeable stratum exists above the water-bearing stratum, the bottom of the casing should extend several feet below the water level in the well at the time of maximum draw-down.

The annular space between the well casing and the natural formation should be completely filled with impervious cement grout to a depth of at least 10 feet. If casings of smaller diameter are used in the lower parts of the well, tight seals should be made between the casings where they telescope. The grouting of wells is always recommended. (See appendix A.)

In many wells of small diameter, especially those which have been put down by the jetting process, the pump cylinder, or working barrel, that contains the plunger and valves is inserted into the casing, and the casing also serves as the discharge pipe. Installations of this type are mechanically not very satisfactory, and in some places they may draw in shallow ground water that is subject to contamination. This process of sinking the casing should not be confused with the ejector type jet pump installation.

Many driven wells are operated by suction pumps attached to the tops of the casings. Such installations are not considered satisfactory because the pumps are likely to require frequent priming with attendant pollution hazard. This is particularly true in cold weather where pumps installed in this manner are not protected against freezing. Alternate freezing and thawing causes the pump leathers to deteriorate rapidly, and freezing may also cause damage to the pump, permitting contaminated material to enter the well.

The casing of a drilled or driven well should be of sufficient diameter to permit the insertion of a pump cylinder attached to a discharge pipe, and the cylinder should be installed at a sufficient depth to be out of danger of freezing and far enough below the static water level so that the pump will not lose its suction and require priming. For satisfactory operation, there should be enough space between the cylinder and casing to allow the water to pass up and down. Figure 2 illustrates a driven well and method of removing the pump. Cylinder leathers and working parts can be removed for repairs without disturbing the drop pipe and well point.

This large casing may be driven, jetted into place, or installed in a drilled hole only to a depth sufficient to accommodate the previously described pump cylinder, and a smaller casing may then be driven to a greater depth. Where there is danger of the discharge pipe freezing in the intervals between pump operations, a weep hole should be

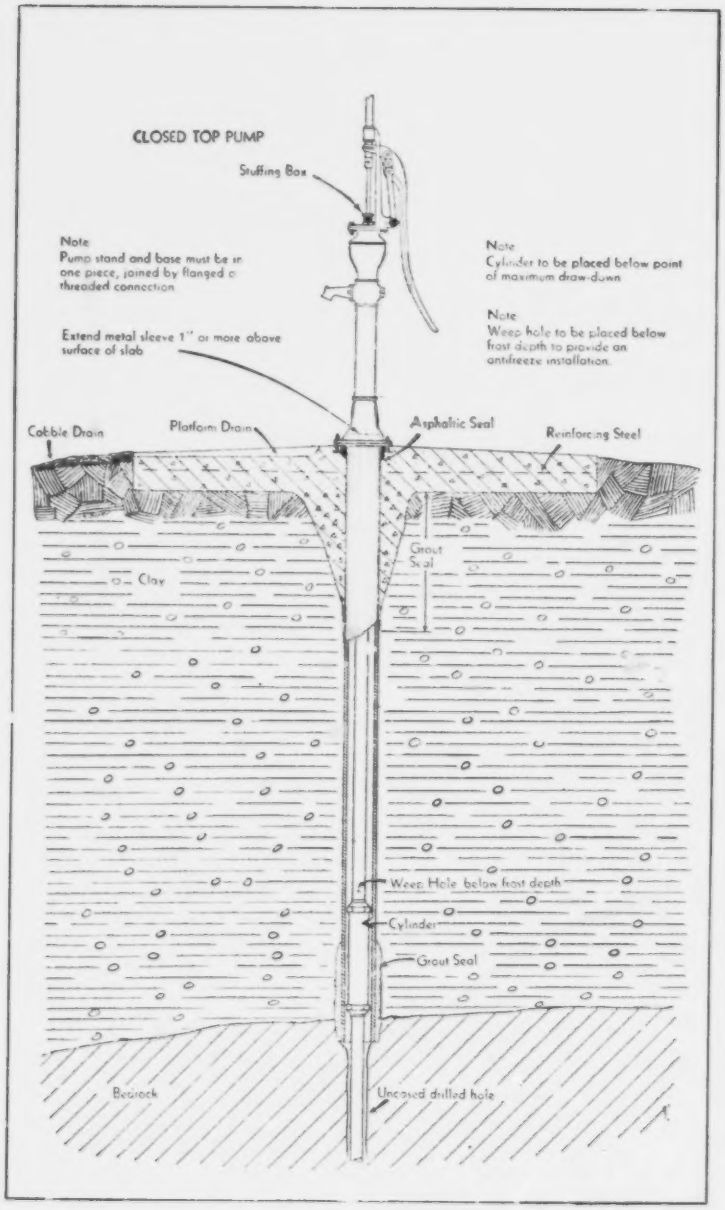

Figure 1. **Drilled well.**

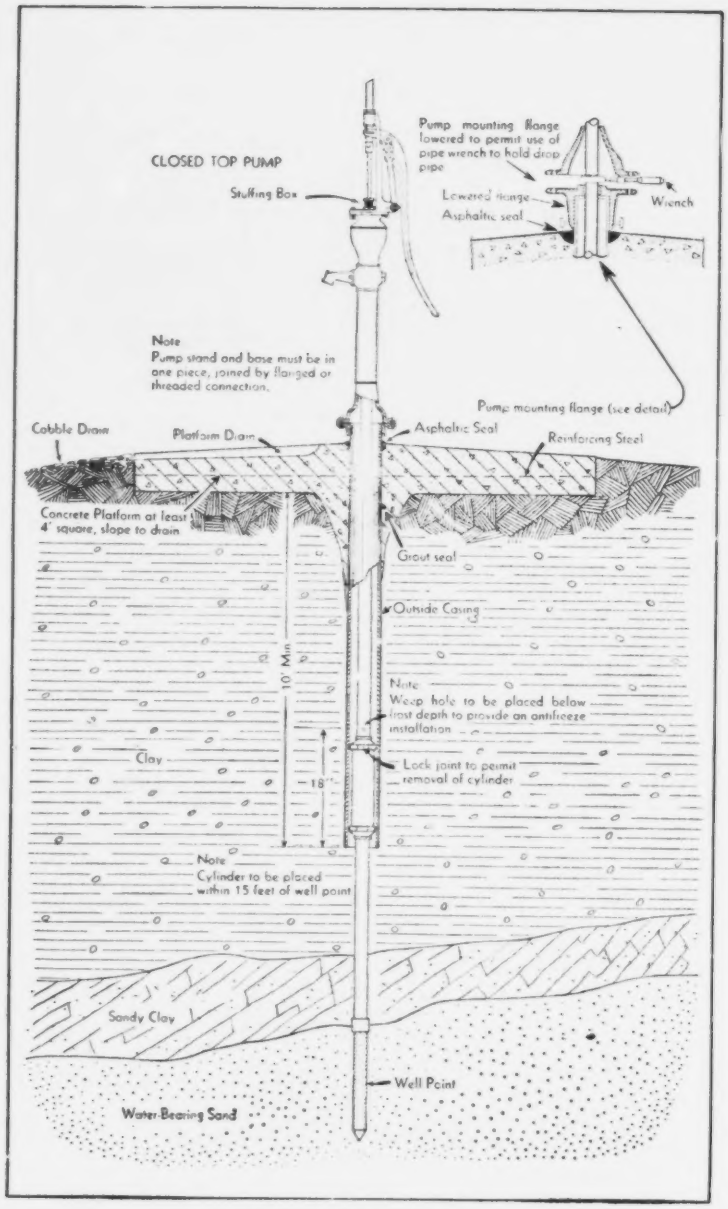
CLOSED TOP PUMP
Stuffing Box
Pump mounting flange lowered to permit use of pipe wrench to hold drop pipe
Lowered flange
Asphaltic seal
Wrench
Note
Pump stand and base must be in one piece, joined by flanged or threaded connection.
Pump mounting flange (see detail)
Cobble Drain
Platform Drain
Asphaltic Seal
Reinforcing Steel
Concrete Platform at least 4' square, slope to drain
Grout seal
Outside Casing
10' Min
Note
Weep hole to be placed below frost depth to provide an antifreeze installation
Clay
Lock joint to permit removal of cylinder
15'
Note
Cylinder to be placed within 15 feet of well point
Sandy Clay
Well Point
Water-Bearing Sand

Figure 2. **Driven well.**

provided in the discharge pipe below the frost line and above the pump cylinder.

Dug and bored wells. Dug and bored wells are less desirable from a sanitary standpoint than are drilled wells, chiefly because it is more difficult to provide a watertight casing for them or to carry the well and casing to the desirable depth.

For such wells, the watertight casing preferably should be of concrete and should extend at least 10 feet below the land surface to exclude surface water and rodents. (Specifications for watertight concrete should be followed.) Where the water table is more than 10 feet below the land surface, it is desirable that the watertight casing extend below the water table (fig. 3).

In order to install the watertight concrete casing, it may be necessary first to provide a form or casing of vitrified-clay pipe, cement-asbestos pipe, galvanized well casing, corrugated-metal pipe, or concrete pipe, leaving an "annular space" or circular opening between this lining and the well hole of at least 6 inches to be filled with concrete. Wood may be used for an inner lining provided it is removed after the concrete has set. The outer lining or form for this concrete wall should be undisturbed earth. This 6-inch concrete wall should be properly reinforced, and the concrete should be placed so as to be free from voids. Wherever practicable, the wall should be poured in one operation.

To simplify the placing of a 6-inch concrete lining in a bored well, a hole of larger diameter than the rest of the well should be bored or otherwise excavated to the depth of the proposed watertight lining (at least 10 feet).

Flowing wells. Regardless of the purpose and use of flowing wells, they should be constructed so that the flow can be controlled. If a flowing well is permitted to flow unrestrictedly when the water is not needed, the artesian head may decrease and the flow eventually may stop. For this reason, some States have enacted laws compelling the control of flow from such wells.

If the water from a flowing well is allowed to run to waste, it may form pools in which malaria-carrying mosquitoes and other disease-bearing organisms may breed. This unsatisfactory condition exists especially in parts of the Atlantic and Gulf Coastal Plains. The prevalence of malaria can be reduced by preventing waste from flowing wells or by disposing of the artesian water in a manner that will not give rise to breeding places for mosquitoes.

The well should be so constructed that water from the artesian stratum cannot rise outside of the permanent well casing and enter permeable strata at a higher elevation. The permanent casing should be seated in the impermeable stratum overlying the artesian water body, and the annular space between casing and drill hole should be filled with cement

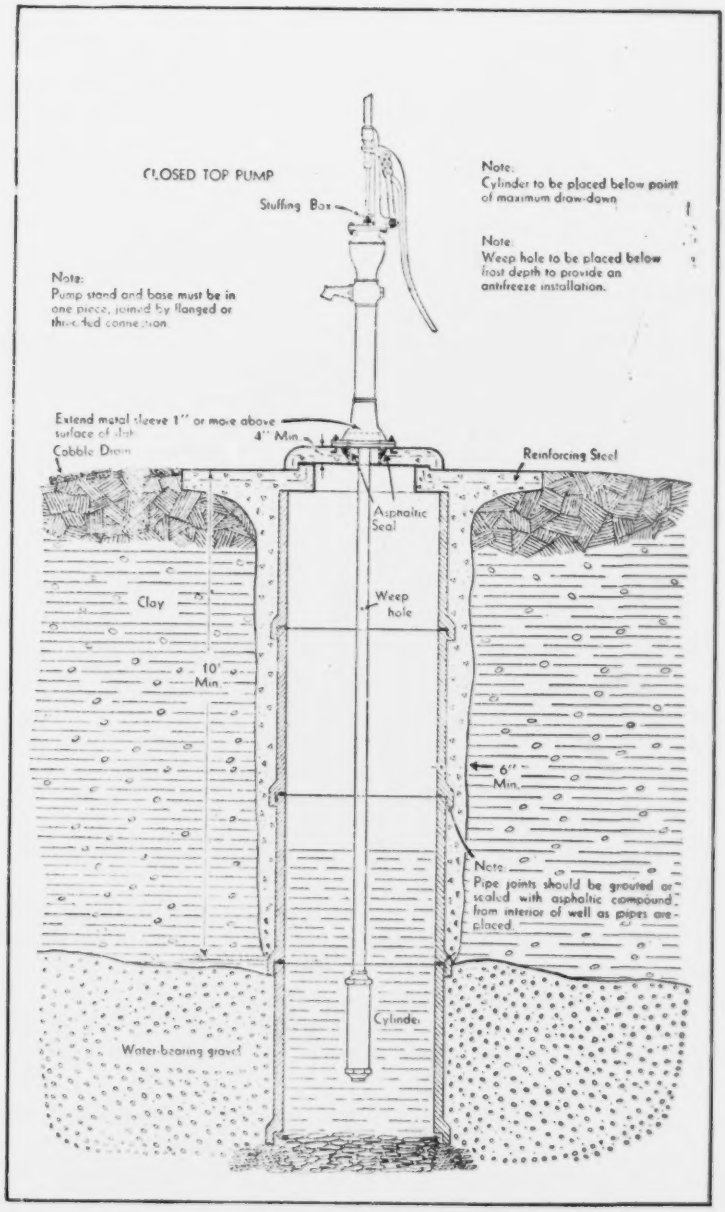
CLOSED TOP PUMP
Stuffing Box
Note:
Cylinder to be placed below point of maximum draw-down
Note:
Weep hole to be placed below frost depth to provide an antifreeze installation.
Note:
Pump stand and base must be in one piece, joined by flanged or threaded connection.
Extend metal sleeve 1" or more above surface of slab
4" Min.
Cobble Drain
Reinforcing Steel
Asphaltic Seal
Clay
Weep hole
10' Min.
6" Min.
Note:
Pipe joints should be grouted or sealed with asphaltic compound from interior of well as pipes are placed
Cylinder
Water-bearing gravel

Figure 3. **Dug well.**

grout. The drill hole should then be continued to the artesian water stratum, and an inner casing should be inserted and joined to the outer casing by means of a suitable watertight seal. The inner casing should extend a sufficient depth below the impermeable stratum overlying the artesian water stratum to avoid the erosive action of the water entering the well. If this precaution is not taken, there is danger of the water cutting a channel around the casing and escaping into permeable formations above.

Well Covers and Seals

Every well should be provided with an overlapping watertight cover at the top of the casing or pipe sleeve to prevent contaminated water or other deleterious material from entering the well through the annular opening at the top of the well casing or pipe sleeve. Pump or power units with closed metal bases can be obtained and properly installed to provide this watertight closure of the annular opening (fig. 9).

In wells equipped with pump or power units having an open-type pedestal or base, or in wells where the pump or power unit is not placed directly over the well (suction and jet pump installations), a watertight seal should be provided for the annular opening. This type of closure may be made of metal or lead packing, or it may be a seal of sand and asphalt compound. There are on the market several types of "well seals" which have proved very satisfactory for sealing this annular space. These are seals made with an expanding rubber gasket between cast-iron plates. They are easily installed, removed, and reinstalled. A mastic seal which may be easily removed and replaced to permit repairs to the drop pipe is desirable.

If the pump is not installed immediately after the casing or pipe sleeve is installed, the top of the casing or pipe sleeve should be provided with a wooden plug or other equivalent closure until the installation is completed.

Every cover, pump platform, or pump-room floor should be watertight and elevated above the adjacent land level. Its surface should be sloped to promote cleanliness by facilitating the rapid removal and diversion of surface and waste water away from the well. These units should be constructed of watertight concrete properly reinforced and sloped from the center of the well casing or sleeve to the outer edges of the slab. The slab or pump-room floor should have a minimum thickness of 4 inches. The well casing or sleeve should extend above the top of the slab or floor at least 1 inch, or such greater distance as may be required to provide the overlapping watertight cover previously specified.

The cover of a dug well should be watertight and should extend downward at least 2 inches over the wall or curbing of the well. Manhole openings in dug well covers are desirable to permit access for

cleaning or pump repair, especially with jet pump installations. If installed, the opening should have 3-inch raised edges and an overlapping (shoe-box type) cover, sealed so as to be watertight. For other wells the cover, pump platform, or pump-room floor should rest on thoroughly compacted earth. In wells equipped with hand-operated pumps, the concrete slab should extend not less than 2 feet from the well casing in all directions.

Reconstruction of Existing Wells

All existing wells used for domestic water supplies which may be subject to contamination should be reconstructed so as to produce safe water, or, if this is not practicable, they should be abandoned and safe supplies developed by constructing new wells, or water should be obtained from other safe sources.

Dug wells with stone or brick casings can often be rebuilt by enclosing existing casings with concrete or by use of a buried concrete slab. Figure 4 illustrates a satisfactory method for reconstructing dug wells.

Care must be exercised on entering wells as they may contain dangerous gases. There may also be a lack of oxygen which may cause asphyxiation of the person entering the well. Before entering a well, it should be opened for several hours, and then a lighted lantern should be lowered to the bottom. If the lantern remains lighted, it should be reasonably safe to enter the well. An additional precaution is to have a rope fastened to the person entering the well and to have one or more attendants who could pull him to the surface at the first sign of danger.

It is suggested that a thorough study be made of the recommendations of this report before the reconstruction of a well to eliminate contamination hazards is undertaken, and that the improvements be planned so that the reconstructed well will conform as nearly as is practicable with the principles set forth. If there is any doubt as to what should be done, advice should be obtained from the State or local health departments.

Protection During Construction

All well developments during construction, reconstruction, or alteration should be adequately protected to prevent contamination of the water at the source or in the system. The diversion of surface water away from the source and the use of water of a safe sanitary quality during construction are essential to prevent contamination of the ground-water supply.

Disinfection After Construction and Repair

Water from a newly constructed well or from an existing well that has been repaired or reconstructed may show an unsatisfactory san-

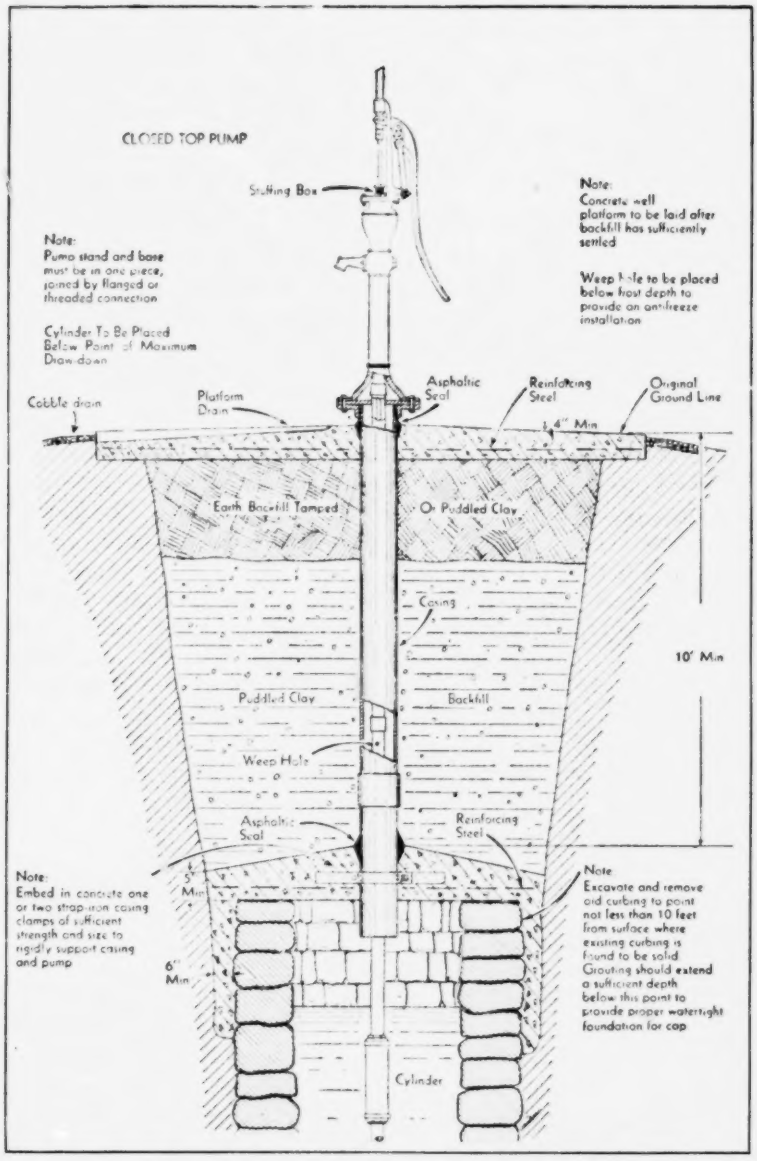
CLOSED TOP PUMP
Stuffing Box
Note:
Pump stand and base must be in one piece, joined by flanged or threaded connection
Cylinder To Be Placed Below Point of Maximum Draw-down
Note:
Concrete well platform to be laid after backfill has sufficiently settled
Weep hole to be placed below frost depth to provide an anti-freeze installation
Cobble drain
Platform Drain
Asphaltic Seal
Reinforcing Steel
Original Ground Line
4" Min
Earth Backfill Tamped
Or Puddled Clay
Casing
10' Min
Puddled Clay
Backfill
Weep Hole
Asphaltic Seal
Reinforcing Steel
Note:
Embed in concrete one or two strap iron casing clamps of sufficient strength and size to rigidly support casing and pump
5" Min
6" Min
Note
Excavate and remove old curbing to point not less than 10 feet from surface where existing curbing is found to be solid. Grouting should extend a sufficient depth below this point to provide proper watertight foundation for cap
Cylinder

Figure 4. **Reconstructed dug well with buried slab.**

itary quality upon bacteriological examination. As noted before, this is usually due to contamination from the equipment, material, or surface water which may be introduced into the well during construction or repair. Even though such contamination may not always be serious in itself, it obscures the meaning of the bacteriological test. Wells and water systems should, therefore, be disinfected following new construction or repair work to remove all traces of contamination. Procedures for disinfection are given in appendix B.

Testing Wells for Sanitary Quality of Water

Before water from any newly developed or reconstructed well is used for domestic consumption, it should be examined bacteriologically.

Following disinfection, the well should be pumped to waste for a sufficient time to remove all traces of chlorine, and a sample should then be collected in a sterile sample bottle.

Abandonment of Wells

Permanently abandoned wells should be filled with selected material to protect the water-bearing formations against possible contamination. Contamination of the water-bearing strata through an abandoned well may result in contamination of existing or future ground-water supplies in the vicinity.

The lower portions of wells are best protected if filled with puddled clay, but where clay is scarce more permeable material can be used if the fill in the upper portion consists of well-puddled clay. In filling dug or bored wells, as much as possible of the lining should be removed so that surface water will not reach the water-bearing strata by way of a porous lining or by following cracks and fissures in the lining.

Abandoned wells should never be used for disposal of sewage or other wastes.

Sanitary Development of Springs

Many of the items discussed with reference to wells are also applicable to spring developments. Certain additional recommendations on sanitary protection of springs follow.

So far as practicable, a spring used for drinking or domestic supply should be enclosed by walls and covers made of concrete or other durable and relatively watertight material. These should be constructed in such a manner as to admit the spring water unrestrictedly, but to exclude surface drainage and other foreign matter. There should be no opening through which water can be obtained by means of cups or buckets dipped into the impounded body of water. Instead, the water supply should be obtained from one or more discharge pipes that pass through the encasing wall. The cover should be movable, or there should be

a covered manhole so that the interior of the encasement can be serviced if necessary, but the cover should be so heavy that it cannot be readily moved or else it should be kept locked. Before attempting to enclose a spring, it should be excavated sufficiently to locate the true spring openings and to insure a firm foundation for the encasing structure (fig. 5).

The water should be impounded in the spring encasement, if possible, to a level high enough to prevent entrance of surface water by seepage or otherwise, even at flood stages, but it should not be kept so high that the incoming flow will be stopped or unduly decreased. This control can generally be maintained by means of one or more discharge pipes set at the proper height in the encasing wall. If the yield of a spring is small but has sufficient head, it may be advantageous to have an overflow pipe near the top of the encasement and a supply pipe with a valve at a somewhat lower level. If water is pumped directly from the encasement, a similar arrangement may be desirable, but the intake pipe of the pump should not extend down to a point that might result in enough lowering of the water level to draw in contaminated surface water. For many springs, a more sanitary arrangement is to have the water discharge by gravity through a pipe into a tight, well-protected reservoir and to pump the water from the reservoir.

At some springs, diversion ditches should be dug to prevent entrance of surface run-off from uphill. The area in the immediate vicinity of the spring should be fenced to exclude animals.

Because of the open nature of the solution channels in tubular springs, very little natural purification takes place in them. Such springs should, therefore, not be developed for drinking or domestic use without providing for effective treatment, unless, by a series of bacteriologic examinations, the water is found to be satisfactory. Periodic bacteriologic examinations of the water should be made as long as such springs are used without treatment of the water. If unfavorable analyses occur, the use of the water from such springs should be discontinued until satisfactory reconstruction or treatment is provided. A marked increase in turbidity after storms may indicate that surface run-off is reaching the spring.

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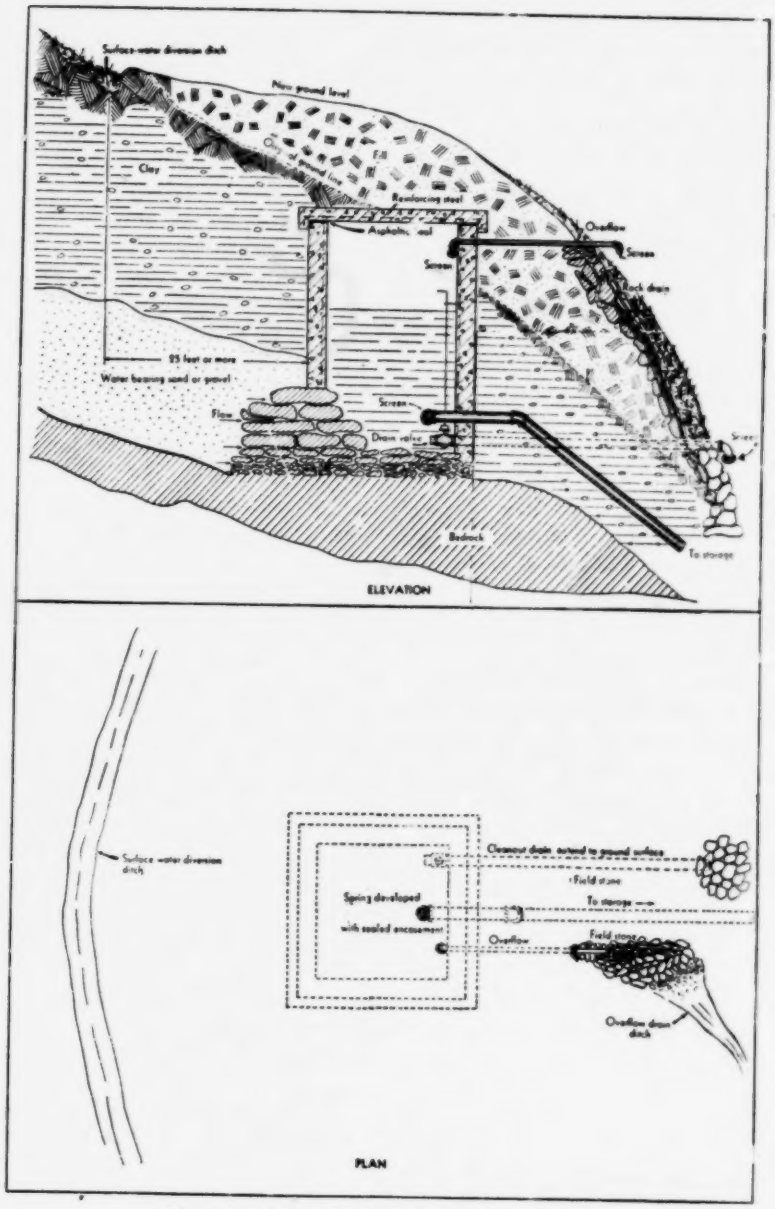

Figure 5. Typical method of spring protection.

III.

Surface Water

CISTERN SUPPLIES

Where the quantity of ground water is not adequate or where the quality of such water is objectionable for domestic use, the storage of rainfall run-off from roof surfaces in cisterns may provide a safe and reasonably potable supply. Cisterns are frequently used to obtain supplemental supplies in rural areas when the available ground water is hard and a soft water is desired for laundry and other domestic use.

Cistern water, although classed in this report as a surface supply, is less liable to contamination than other surface sources. It is an important source of domestic water supply in certain rural areas.

The catchment area from which rain water is collected is usually the roof of the dwelling or other farm building. Where the volume of rain water needed for storage is in excess of that obtainable from available roof surfaces, protected paved areas are sometimes used. The quality of the water obtained from a roof surface is affected by the roof surface used and the design and maintenance of gutters, downspouts, bypasses, and filtering devices. In general, a smooth dense roof surface does not catch and hold wind-blown dust and debris as does a rougher type of roof. The soluble matters leached from some roofing materials, particularly from certain shingle stains and from fragrant and colored woods, may impart taste and color to the water collected. Roof gutters collect leaves and other material and should be designed to facilitate easy and frequent cleaning.

The first washings of a roof surface at the beginning of a rain will carry a maximum concentration of a wind-blown pollutional material. Manual or automatic devices are frequently installed to provide for the bypassing of this water. The discharge should be drained to a point where it will flow by gravity away from the cistern and building foundations.

While the bacterial quality of cistern water may be satisfactory, its usefulness from the standpoint of taste and odors is frequently impaired

by the decomposition of organic material contained in the stored water. Filtering devices may be installed and, if properly maintained, will be effective in removing suspended foreign matter washed from collecting surfaces. Because such filters must operate intermittently and at high rates during rainfall, they cannot be regarded as dependable for the removal of bacterial contamination, and the disinfection with chlorine compounds of cistern water intended for drinking purposes is recommended.

Sand and/or charcoal filters are commonly used for the removal of organic material. Typical designs of filters are illustrated in figures 6, 7, and 8. The design used should facilitate the thorough cleaning of the filtering material at regular intervals without disturbing or polluting the water stored in the cistern. Filters which are not cleaned regularly may actually add to the bacterial content of water passing through them.

CISTERN LOCATION, DESIGN, AND CONSTRUCTION

While cisterns are usually located with primary regard for convenience in usage, certain sanitary precautions should be observed. The site should be higher than the surrounding area and graded to provide good drainage. All sewage disposal installations should be at a safe distance (not less than 50 feet) and at a lower elevation.

Underground cisterns are generally preferable because of economy in construction, relatively low water temperatures even in warm climates, and protection from freezing in cold climates. However, where drainage and ground-water conditions are unsatisfactory and climatic conditions permit, above-ground cisterns are sometimes used. Cisterns should not be located in basements because they may be flooded by contaminated water.

The size of cistern needed will depend on the water requirements of the family or farm and can be estimated from the table in part I of this report. Storage capacity will also depend on the local rainfall characteristics, upon the length of time between seasons of heavy rainfall, and upon the size of the roof catchment area in relation to the cistern storage volume. Capacity in excess of that required for normal rainfall conditions must be provided as a factor of safety for the abnormally dry year.

Cisterns should be of watertight construction with smooth interior surfaces. Manhole or other covers should be tight to prevent the entrance of light, dust, surface water, insects, and animals.

Manhole covers should have a watertight frame with edges which project about 4 inches above the level of the surrounding surface. The edges of the cover should overlap the frame and project down-

ward at least 2 inches. The covers should be provided with locks to avoid the danger of contamination and occurrence of accidents.

Inlet, outlet, and waste pipes should be properly screened, and no connection should be made between cistern drains and sewage drains.

Underground cisterns can be built of brick, stone, or reinforced monolithic concrete, preferably the latter. Brick or stone must be low in permeability and laid with full Portland cement mortar joints. Two ½-inch plaster coats of 1:3 Portland cement mortar on the interior surface will aid in providing essential waterproofing. A hard impervious surface can be secured by troweling the final coat before it fully hardens. Brick should be wet before laying. High quality workmanship is required and the use of unskilled labor for laying brick or stone is not advisable.

Figures 6, 7, and 8 show suggested cisterns of reinforced concrete. A dense concrete should be used to obtain watertightness.

All masonry cisterns should be allowed to cure for a month or more before being used. Occasional sprinkling with water will aid in converting the free lime in the cement so that less will be dissolved in the stored water. If immediate use of the cistern is desired, as soon as the concrete has hardened it may be scrubbed with vinegar, a 10-percent muratic acid solution, or a solution of 4 pounds of zinc sulfate per gallon of water. Thorough flushing after treatment is essential. Where quantity of water permits, a new cistern should be pumped out two or three times prior to use of the water for drinking.

OTHER SURFACE WATER SUPPLIES

The use of surface water other than that collected on roofs or other controlled catchment areas and stored in cisterns for rural domestic use presents many difficulties and is to be avoided when possible. The danger of contamination and consequent spreading of such diseases as typhoid fever and dysentery is great, especially when small streams and open ponds and reservoirs in populated areas must be used as sources of supply. Clear water is not always safe, and the idea that running water purifies itself within a stated distance is incorrect.

The physical and bacteriological contamination of surface waters, except in the most sparsely settled areas, makes it necessary to regard such sources of supply as unsafe for domestic use unless a reliable purification process is provided. The treatment of surface waters, to assure a continually safe supply, is not usually practicable for rural domestic purposes because of the expense and labor required for maintenance. For this reason water from surface sources is used mainly for stock watering, irrigation, fire fighting, and similar purposes. However, if used for domestic purposes, such water should be treated as described in

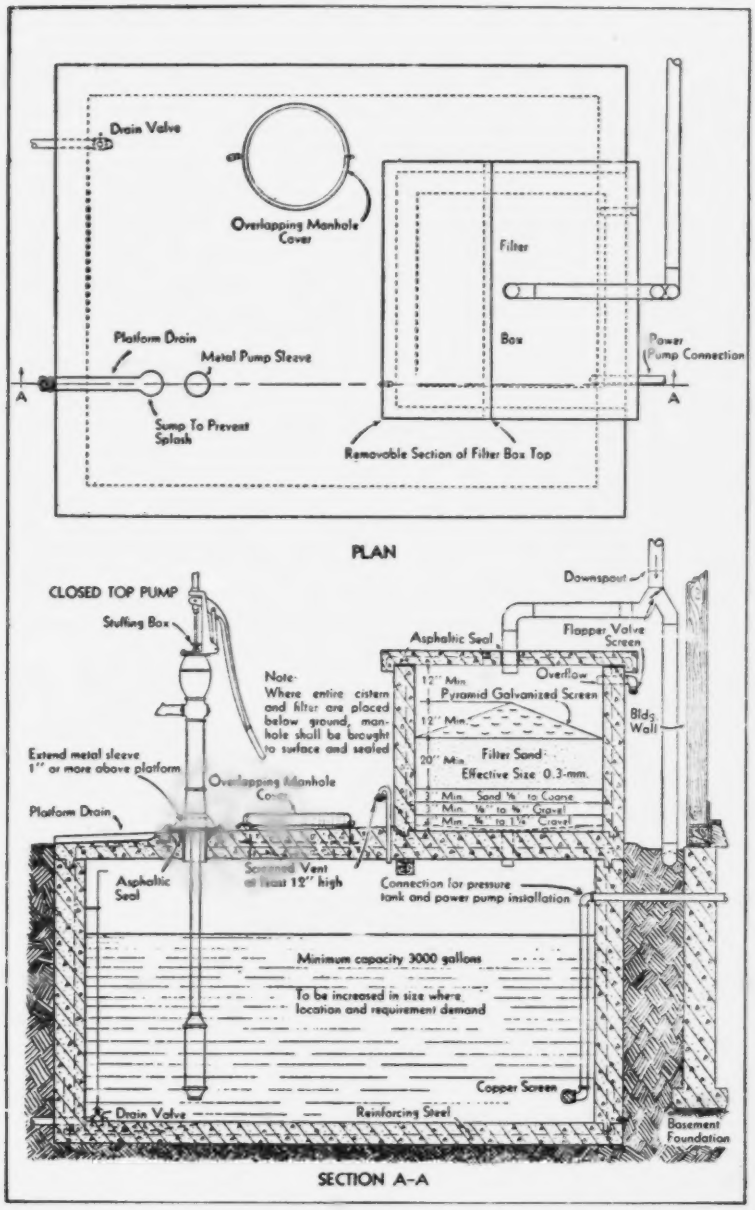

Figure 6. **Cistern with sand filter (pump installation optional).**

DIMENSIONS SUGGESTED FOR INDICATED ROOF AREAS AND ANNUAL RAINFALL OF 30" (ASSUMING TOTAL PRECIPITATION ENTERS THE TANK)				
ROOF AREA SQ. FEET	RAW WATER TANK (DEPTH 2'-6")	FILTER (DEPTH 3'-0")	FILTERED WATER TANK (DEPTH 10'-0")	FILTERED WATER TANK STORAGE IN GALS.
400	3'-6" x 9'-9"	3'-6" x 3'-6"	8'-4" x 12'-0"	7,500
600	4'-0" x 12'-9"	4'-0" x 4'-0"	10'-0" x 15'-0"	11,250
800	4'-9" x 14'-6"	4'-9" x 5'-6"	12'-0" x 16'-9"	15,075
1000	4'-9" x 17'-9"	4'-9" x 6'-0"	12'-6" x 20'-0"	18,750
1200	6'-0" x 17'-9"	6'-0" x 6'-0"	15'-0" x 20'-0"	22,500

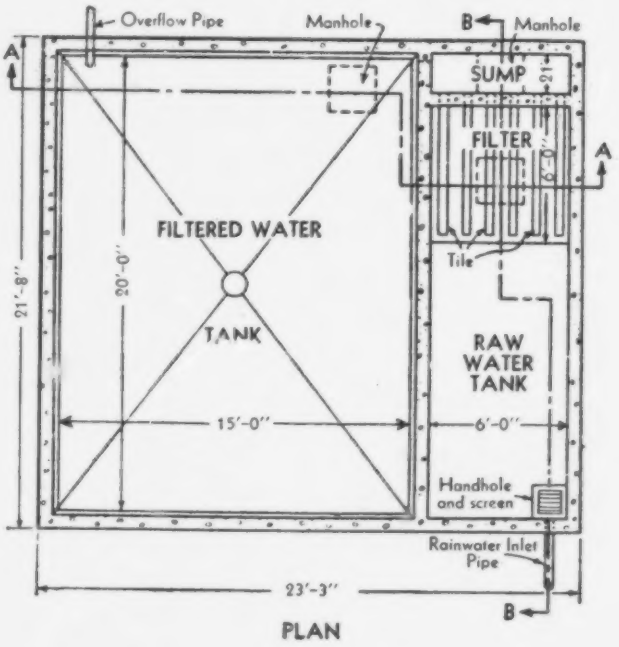

Figure 7. **Plan of rain-water tank, filter, and cistern (see fig. 8 also).**

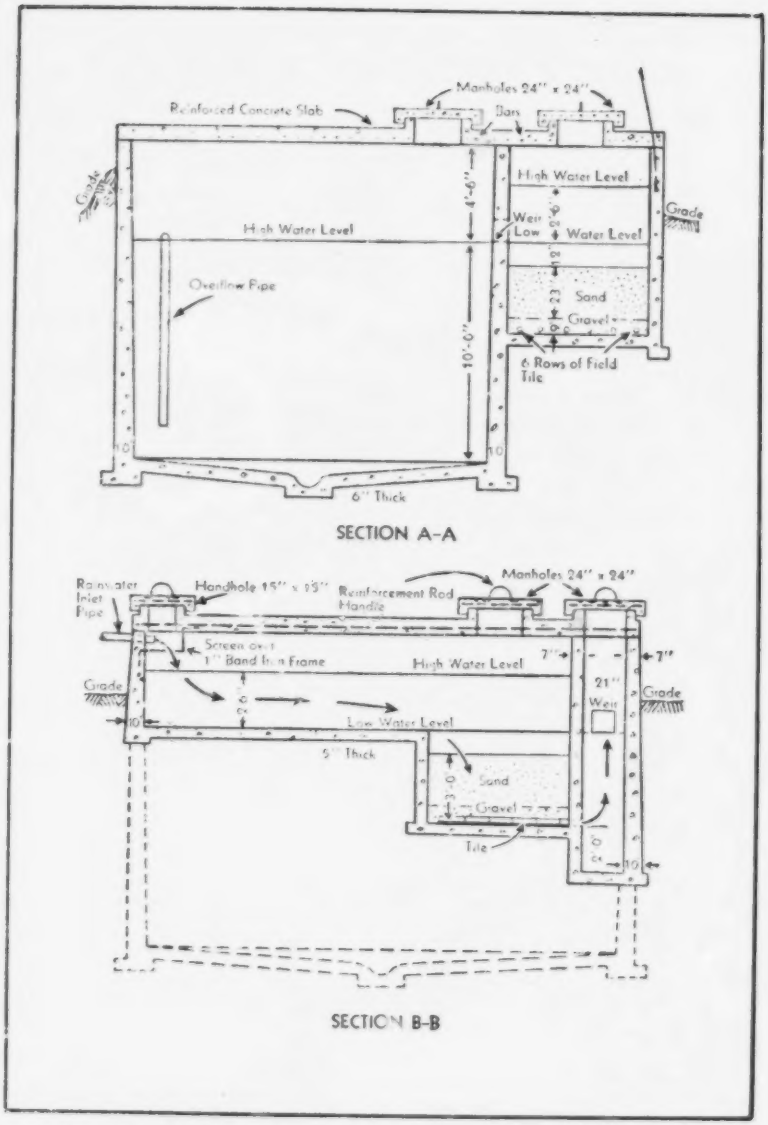

Figure 8. Sections of rain-water tank, filter, and cistern (see fig. 7 also).

part IV of this report, and examination should be made at regular intervals to determine its safety and to prevent the possible contraction of serious diseases.

When surface waters must be used, next in preference to cisterns supplied with rain water, ponds and reservoirs are the most practical sources of surface water supplies for use on the farm as they can be more easily controlled from a sanitation standpoint than streams, lakes, swamps, or ditches. Water from irrigation ditches provides an important source in certain regions. Quiescent waters permit settlement of sediment, including a large portion of the pathogenic bacteria, so that the load on the purification process is reduced.

Ponds and reservoirs used for water supply should be protected against contamination from sewage disposal areas and barn lots. A minimum horizontal distance of 100 feet from any possible source of contamination is recommended; greater distances are needed where gravel, limestone, or other porous formations exist. Livestock and campers should be excluded from watershed areas and no swimming allowed in settling or storage basins. Ponds and reservoirs used for domestic water supply should be kept as free from organic matter as possible. In general, unless elaborate treatment facilities are provided, ponds and reservoirs used to store water intended for human consumption should not be used for recreational purposes because of the hazards of human pollution.

Watershed areas and the tops of earth dams should be protected against erosion by the use of vegetative covering, thus reducing silting and the turbidity of the water to be purified.

Intakes in streams should be located upstream from sewer outlets or other sources of contamination. In lakes as much distance between sources of pollution and water intakes as is practicable should be obtained. The intake should be extended away from shore to avoid high turbidities, rapid currents, weedy areas, and shore pollution.

IV.

Water Purification

Nature employs sedimentation, filtration, aeration, sunlight, nitrification, and other means of purifying water, but purification by nature is not dependable.

Bacteria, which are numerous in waters at or near the earth's surface, are reduced in number by the process of filtration, by the depletion of oxygen or its conversion to carbon dioxide through the action of organisms in the soil, and by detention underground for long periods under conditions unfavorable for bacterial growth. However, where water flows through underground fissures or channels it can carry contamination for miles. Therefore, ground water is not necessarily safe. On the other hand, the quality of the effluent of small water-treatment plants, which may operate intermittently and in most instances without technical supervision, depends largely upon the human element, which is frequently unreliable. In the majority of cases, therefore, small water supplies obtained from properly located wells or springs are likely to be superior to treated surface supplies.

The fallacious belief that flowing water purifies itself in various distances has led to unjustified feelings of security. Under certain conditions the number of bacteria in flowing water may increase instead of decrease.

Treatment of surface-water supplies by persons untrained in this field is not likely to be dependable or satisfactory because technical control is not available. If surface waters must be used and treated, advice should be obtained from competent authorities. The following sections indicate some of the treatment processes used to purify water.

AERATION

Aeration may be used to oxidize iron and remove odors from water, such as those caused by hydrogen sulfide and algae. It is also effective in increasing the oxygen content of water deficient in dissolved oxygen.

The flat taste common to cistern water and distilled water is often remedied by addition of dissolved oxygen in this manner. Carbon dioxide and other gases that increase the corrosiveness of water can be largely eliminated by effective aeration, although the increase in oxygen content may partially offset the advantage of the decrease in carbon dioxide.

Aeration of water results in the oxidation of its dissolved ferrous iron and thereby changes the iron into the insoluble ferric form. Sometimes a short period of storage permits the insoluble iron to settle; in other instances, the precipitated iron can not be removed successfully except by filtration. Chemicals and special zeolites are also utilized to improve the quality of water supplies having a high iron content. Excess iron in water causes rust spots on laundry and stains on plumbing fixtures.

For rural water supplies, aeration can be accomplished by allowing the water to cascade over a spillway, allowing it to drip in numerous jets from ¼-inch sievelike perforations in the bottom of the tank, or spraying it from atomizing nozzles. Aeration basins equipped with spray nozzles, although used in municipal waterworks, are generally too elaborate for adaptation to rural water-supply installations.

Precautions should be taken to prevent contamination of the water during the aeration process. Aerating devices should preferably be screened to prevent access to insects such as the chironomus fly. Eggs laid by this fly develop into a small red worm or larva commonly known as a bloodworm.

SEDIMENTATION [2]

Comparatively heavy suspended matter can be settled out by gravity in a pond or settling tank. A settling basin, to carry on this process efficiently, should be so designed that entrance velocities are reduced as soon as possible after the water enters it. Inlets should be so arranged that the dispersion of the incoming silt-laden water is uniform across the entire width of the basin as the water slowly flows to the outlet at the opposite end. Baffles can be used to aid in directing the flow. Cleaning and repairing will be facilitated by dividing the basin into two sections, one of which may be used independently of the other. When the suspended matter is colloidal or very fine, it may take days to settle unless a chemical coagulant, such as aluminum sulfate, is added to the water to collect the fines into clusters or flocs that will settle promptly. A detention period of several hours should be allowed for this sedimentation of the floc.

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[2] Manual of Water Quality and Treatment. American Water Works Association, 1941.

FILTRATION

Filters remove solid particles that are suspended in the water, but do not necessarily remove the bacteria except as they are entrained in the sediment caught in the filter. The coarser solids should be removed by sedimentation prior to filtration. The water is usually chlorinated after filtration.

Slow-sand filters, using graded sand or other similar acceptable filtering media, will clarify water when operated at a rate of 25 to 50 gallons per 24 hours per square foot of filter.

During operation the water level is kept above the sand to protect the silt film that accumulates on the surface of the sand, thereby aiding filtration, and to produce the desired head on the filter bed so that the water will flow through. When the sand becomes dirty, it can be washed and reused. Unless there is a continuous flow through such a filter, bacteria in the filtrate are likely to be higher than in the influent. If diatomite in the form of diatomaceous-silica slurry is used as a filtering medium, a special type of pressure filter is required.

It is desirable to have competent engineering advice in the construction of any filter, particularly for rapid-sand filters which operate at a rate of about 3,000 gallons per 24 hours per square foot of filter. To permit this high rate of filtration, it is essential that effective coagulation and sedimentation be provided prior to filtration.

The possibility that an uncleaned filter may collect high concentrations of bacteria and even provide a favorable breeding ground must not be overlooked. For this reason considerable hazard results from the use of small household filters attached to faucets where contamination from handling and the accumulations screened from the water are likely to be carried through in concentrated doses by the high velocities from the pipe. The use of these small household filters for bacteriologic purification is not recommended.

DISINFECTION [3]

Methods of disinfecting water are of utmost importance because the removal of disease-producing bacteria and organisms from drinking water is a prime prerequisite of its safe use.

Chlorine in some form offers the most dependable disinfectant. Chlorine can be applied to the water as a chlorine solution in powder form (high-test hypochlorite or other commercial products containing from 40 to 70 percent chlorine) or as a chlorine gas. There are avail-

[3] Public Health Service Drinking Water Standards, Reprint No. 2697, 1946. Water Development and Sanitation, U. S. Forest Service. Manual of Water Quality and Treatment, American Water Works Association, 1941.

able numerous small capacity chlorinators that are suitable for camps, individual dwellings, hotels, or swimming pools. Connected to a gravity or pumped water supply, a unit feeds hypochlorite solution from chlorine-resistant containers (earthenware or glass) through plastic or rubber tubing into the water being treated at a rate for proper disinfection. The chlorinator may be operated by various means to feed the desired amount of chlorine or chlorine solution into the water system. In some instances it may be connected with the water pump to feed chlorine only when the pump is in operation.

Applications of chlorine usually range from one to several parts per million depending upon the amount of chlorine absorbed by the materials in the water and the residual chlorine required to keep the water safe. A 30-minute contact period with the water is desirable to permit the chlorine to destroy the existing organisms. The chlorine remaining in the water after it is initially disinfected is known as "residual chlorine." To insure adequate disinfection of the water, it is necessary that some residual chlorine be present after the required contact period of 30 minutes. This residual chlorine in the water also protects it from recurring contamination for a certain period of time, the length of which can be closely estimated after periodic tests are made of the residual chlorine. Small test kits are available at nominal cost. A residual of 0.5 part per million is sufficient ordinarily.

One part per million of chlorine represents 8⅓ pounds of chlorine per million gallons of water treated. The calculation of chlorine dosage is covered more fully in appendix B.

The quality of chlorinated water depends primarily on the competence of the operator and the care and maintenance of the equipment. If the raw water is potentially dangerous, only continuous uninterrupted disinfection will assure its safety.

EMERGENCY DISINFECTION

Emergency chlorination may be accomplished by dissolving 1 heaping tablespoonful of chloride of lime (approximately ½ ounce) to 2 gallons of water. This will give a stock chlorine solution having a strength of about 470 ppm since the available chlorine in the chloride of lime is about 25 percent of its weight. To disinfect the water to be used for drinking, add the stock chlorine solution to it in the ratio of 1 part of stock chlorine solution to 100 parts of water to be disinfected. A period of 30 minutes should be allowed between treatment and use. The treated water may have a distinct chlorinous taste but will not be harmful. The taste may be removed by dissolving a small crystal of sodium thiosulfate in the water after it has been in contact with the chlorine for

30 minutes. Small portable chlorinating units for accurately treating measured flows of water are most useful. Such units, however, require maintenance and supervision of operation for effective results.

Where emergency disinfection is employed pending analysis of a water supply, the effect of varying composition of waters on dosing efficiency must be kept in mind. For example, muddy water uses up the chemicals and reduces the effectiveness of a given quantity of disinfectant.

Iodine disinfection may be accomplished by adding 2 drops of tincture of iodine (7 percent) per quart of water and allowing it to stand 30 minutes before use.

Iodine may impart a medicinal taste to water which may be removed, after the water has been allowed to stand for the 30-minute period, by the addition of sodium thiosulfate solution (7 percent) in an amount equal to the quantity of iodine which was used.

Distillation is very effective as a disinfecting process, but the resulting flat taste is generally objectionable.

Boiling for 5 minutes is a simple and effective emergency measure for disinfecting water.

SOFTENING [4]

Two water-softening processes are available:

1. The conversion of soluble bicarbonates of calcium and magnesium to insoluble calcium carbonate and magnesium hydroxide by the application of lime, and the conversion of calcium and magnesium sulfates, chlorides, and nitrates to insoluble calcium carbonate and magnesium hydroxide by the application of soda ash and lime.

2. The conversion of soluble salts of calcium and magnesium to calcium and magnesium zeolites by passage through a zeolite filter. The calcium and magnesium removed in the filter are replaced by sodium. The lime-soda softening process is generally not practicable for household use because of the technical knowledge and control required to give successful results. Commercially manufactured zeolite softeners are widely used. Their operation is not difficult; hence, they are adapted for use on the private water supply. In certain types of automatic zeolite softeners, it is simply necessary to regenerate the zeolite in the softener occasionally by contact of the filter media with a solution of common salt.

Water can be softened by the addition of ammonia, borax, or washing soda, but the uncertainties attached to such home-made applications make them less desirable than a treatment based on analysis of the water, except when used on a very small scale, as for laundry purposes.

[4] Water Supply and Treatment, National Lime Association Bulletin 211.

Commercial softening or water-conditioning compounds of unknown composition or effect should not be used in water intended for drinking or cooking until the advice of the State department of health as to their safety is obtained, in order that harmful substances will not be added to an otherwise safe supply.

ALGAE CONTROL

Algae, some of which are the blue-green growths that produce scum and objectionable odors in stored waters and in exceptional cases kill cattle, can generally be controlled by treatment of the water with copper sulfate (blue vitriol) or, when feasible, by covering the storage unit so as to exclude sunlight.

In small reservoirs or ponds the required dose of copper sulfate can be dissolved in water and applied by a sprinkling can to the body of water. In large ponds or reservoirs the copper sulfate may be tied in a clean gunny sack and this sack dragged through the water from a boat in lanes 10 to 20 feet apart until the copper sulfate is completely dissolved.

Control will be easier and more effective if the treatment is applied before the algae bloom or reach their maximum growth and development.

One treatment will be effective for a varying length of time, depending upon sunshine, reseeding, and local conditions. Several treatments per season are generally required. Some municipalities treat open distributing reservoirs as often as twice a month in order to avoid unexpected blooms of algae and the accompanying troubles from taste and odors.

The dosage of copper sulfate varies with the particular species of organism involved; however, a dose of 3 pounds per million gallons will generally control all but a few of the growths likely to cause trouble in drinking water (3 pounds per million gallons equal 5 ounces in 100,000 gallons or 1 ounce in 20,000 gallons). The approximate doses of copper sulfate in pounds per million gallons which should not be exceeded to avoid killing various kinds of fish are as follows:

Kind of fish	*Copper sulfate (pounds per million gallons)*
Trout	1.2
Carp	2.5
Suckers	2.5
Catfish	3.5
Pickerel	3.5
Goldfish	4.0
Perch	6.0
Sunfish	10.0
Black bass	17.0

V.

Pumping, Distribution, and Storage

PUMPING EQUIPMENT

Equipment in general use for raising water from supply sources in rural areas falls generally into four classifications: (1) Bucket devices, (2) plunger or reciprocating pumps, (3) rotating pumps (centrifugal and turbine), and (4) jet or ejector pumps. Other types applicable include air-lift pumps and hydraulic rams.

The bucket devices, generally hand-powered and used for drawing water from cisterns, dug wells, and some bored wells, include (a) the simple bucket and rope or windlass, (b) chain bucket pumps, consisting essentially of a series of metal buckets attached to an endless chain extending from below the water level to above the land surface where it passes over a toothed wheel enclosed in a covered housing, and (c) chain-and-plug pumps in which rubber or wooden plugs on an endless chain form a close fit in a metal or wooden tube extending below water level, and function as buckets to carry the entrained water to a discharge spout near the top of the structure.

The various features of design and operation of these bucket devices present problems of sanitation which justify selection of other types of pumps permitting better protection of the water supply. As no satisfactory solution has yet been found to the problem of safeguarding a supply serviced by the simple bucket, this device is not recommended. The main objection to the endless-chain devices is that considerable maintenance is necessary which, if neglected, results in danger of contamination.

Reciprocating or cylinder pumps have, perhaps, the widest application for small systems in rural areas. They are adapted to manual, windmill, gas or oil engine, and electric-motor operation. The suction type is capable of raising water from shallow sources where the dynamic or pumping level of the supply is within approximately 22 feet measured vertically below the cylinder.

Rotating pumps include the centrifugal rotary and turbine types, single or multistage, with the mechanism located at the bottom of a discharge column below water level. Most of these are power-operated through an enclosed shaft extending from the electric motor or other power source at the well top. Water pumped through well-designed pumps of these types is not likely to be contaminated by the pumping process.

Jet pumps, also called ejector-type pumps, utilize the ejector principle of pumping water into the bottom of the drop-pipe installation through an orifice or jet which forces the water in the pipe from the well to the surface. They are installed in both shallow and deep wells. However, provisions should be made to permit easy access to the jet mechanism for cleaning and repairs.

HAND-PUMP INSTALLATIONS

The pump equipment for hand-pumped wells and cisterns should be so constructed and installed as to prevent the entrance of contaminating water or material either into the well or into the water that is pumped.

Sanitation specifications for a properly designed and installed pump should provide the following protective features:

1. The pump head should be designed to prevent contamination by hands, dust, rain, birds, flies, and similar sources from reaching the water chamber of the pump.
2. The pump base should be so designed as to facilitate a waterproof seal with the well cover or casing.
3. The pump cylinder should be installed near or below the static water level in the well so that priming will not be necessary.
4. The design should provide for frost protection pump drainage within the well.
5. The installation should be designed to facilitate necessary maintenance and repair, including overhead clearance for removing rods and pipe.

The pump heads on most force pumps are designed with a stuffing box surrounding the pump rod, thus providing reasonable protection against contamination. Ordinary lift pumps with slotted pump-head tops are open to contamination and should not be used. The pump spout should be of the closed downward-directed type.

The pump base should be designed to serve a twofold purpose: first, to provide a means of supporting the pump on the well cover or casing top; and second, to protect the well opening or casing top from the entrance of contaminating water or other material. The base should be of the solid, one-piece, recessed type, cast integrally with or threaded to the pump column or stand. It should be of sufficient diameter and depth

to permit a 6-inch well casing to extend at least 1 inch above the surface upon which the pump base is to rest. Provision should be made for fastening the pump base rigidly to the well cover or casing top to prevent movement. The use of a flanged sleeve imbedded in the concrete well cover or a flange threaded on the top of the casing to form a support for the pump base is recommended. Suitable gaskets should be used to insure tight closure. To insure rigidity and the stability of the pump-base closure, the pump should be suitably braced against movement. Figure 9 illustrates methods of mounting pumps to assure a safe, watertight connection to the slab or pump platform.

The protective closing of the pump head, together with the pollution hazard incident to pump priming, makes it essential that the pump cylinders be so installed that priming will be unnecessary.

POWER-PUMP INSTALLATIONS

The application of power makes it possible to consider additional types of pumping equipment. Turbine and centrifugal pumps may be designed to meet almost every pumping need. A combination centrifugal water-ejector pump has been developed to provide a small-capacity deep-well type suitable for use in any type well.

Hydraulic rams, especially in hilly areas, are suitable for special spring or surface reservoir installations where the quantity of water to be lifted is small and the available water supply is adequate to furnish power for low-head pumping. Hillside springs are the most common source of supply.

The sanitation specifications pertaining to hand-operated pumps are in general equally applicable to power-driven installations.

The base plate of a power-operated pump placed immediately over the well should preferably be designed to form a watertight seal with the well cover or casing. As in the hand-operated pump, the base should be recessed to permit the casing or pipe sleeve to extend into it at least 1 inch above the foundation upon which the pump base rests. All well casings for power-pump installations should extend at least 6 inches above the pump-room floor or platform slab. In installations where the pump is not installed directly over the well or where an open-type pump base is used, the well casing or pipe sleeve should extend at least 6 inches above the floor of the pump house, and the annular space between the casing and the suction pipe should be closed with an acceptable watertight packing or seal.

Power-pump installations usually require enclosure in some form of protective housing. The pump-room floor should be of watertight construction, preferably concrete, and should slope away in all directions from the well or suction pipe. Due to the protective housing, it should

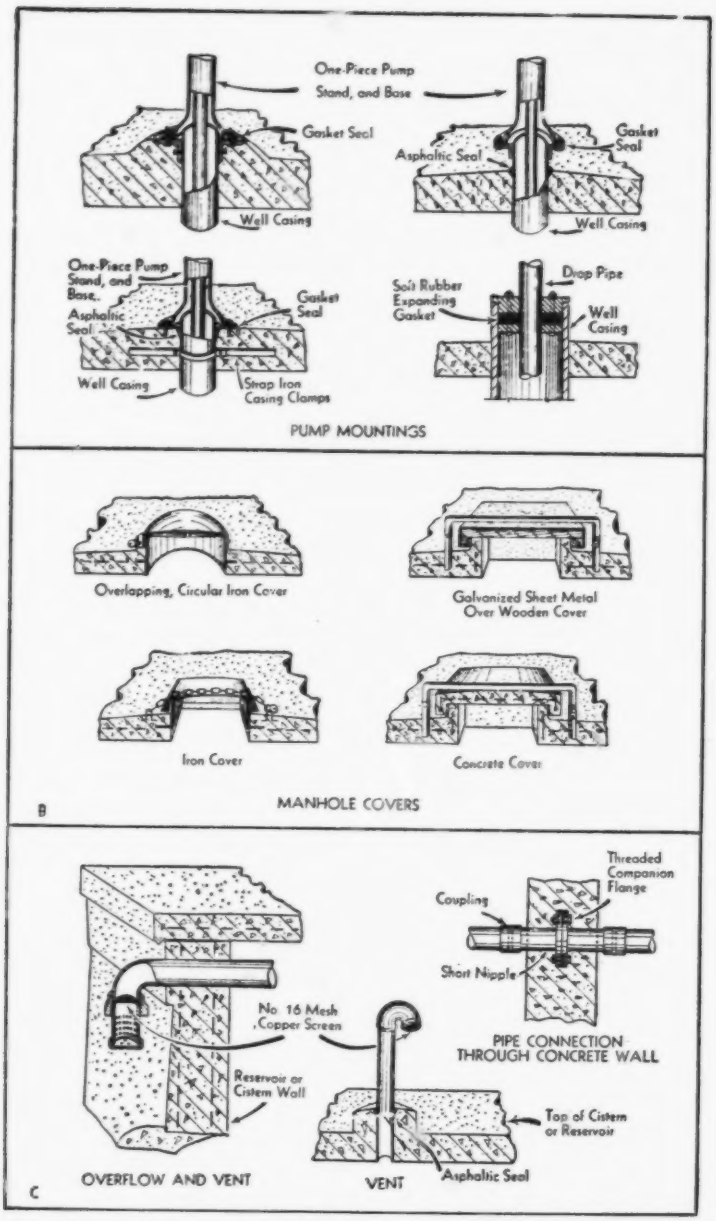

Figure 9. **Typical pump mountings, manhole covers and piping installations.**

not be necessary to use an underground discharge connection with a power pump. The necessary protection from freezing temperatures can be provided for a motor-operated pump through the installation of a thermostatically controlled electric heater. Automatic frost protection drain-back devices can be designed to drain exposed piping where heating is not practical. For individual installations in rural areas, a 100-watt light bulb may give the needed protection if the pump house is properly constructed and the light wired for continuous burning.

Where an underground discharge is provided, it can be installed without the use of a pit below the ground surface. Figure 10 illustrates a method of providing an underground discharge below the frost line. This type of installation is particularly applicable to wells in which the pump cylinder is of larger diameter than the drop pipe.

Experience with installations of this type indicates that when a pressure tank is provided in the distribution system there is no difficulty with water hammer. Sometimes it may be necessary to provide an air chamber on the discharge line from the well located near the pump.

If the pumping rate makes the use of an air-relief vent necessary, the open end of the vent should be at least 18 inches above the pump-room floor. The end of the vent pipe should open downward and be protected by proper screening.

Certain types of power pumps require the filling of the pump system with water for priming or water-lubrication purposes before being started. Water thus returned to the pump should be taken from the original source for which the pump is used through bypass piping in the connected discharge line from the pump to avoid contamination.

It is desirable to provide a water-sampling cock on the discharge line from power pumps which also may be used for releasing any trapped air in the system.

DISTRIBUTION

Distribution lines for small systems are ordinarily made up with standard threaded galvanized-iron or steel pipe and fittings. Cast iron is available for pipe sizes of 2 inches or more. Where corrosive waters are encountered, brass, copper, or lead pipes are frequently used to prolong the life of the plumbing. Use of these metals with corrosive waters may result in the presence of lead, copper, or zinc in objectionable amounts in the delivered water. Corrosion prevention treatment is generally not feasible for a small private water supply because of the necessity for technical knowledge and control. Water may be made less corrosive by exposure of the water in beds of crushed limestone, a procedure which is automatic and requires no supervision.

The selection of piping materials should, therefore, be made with due

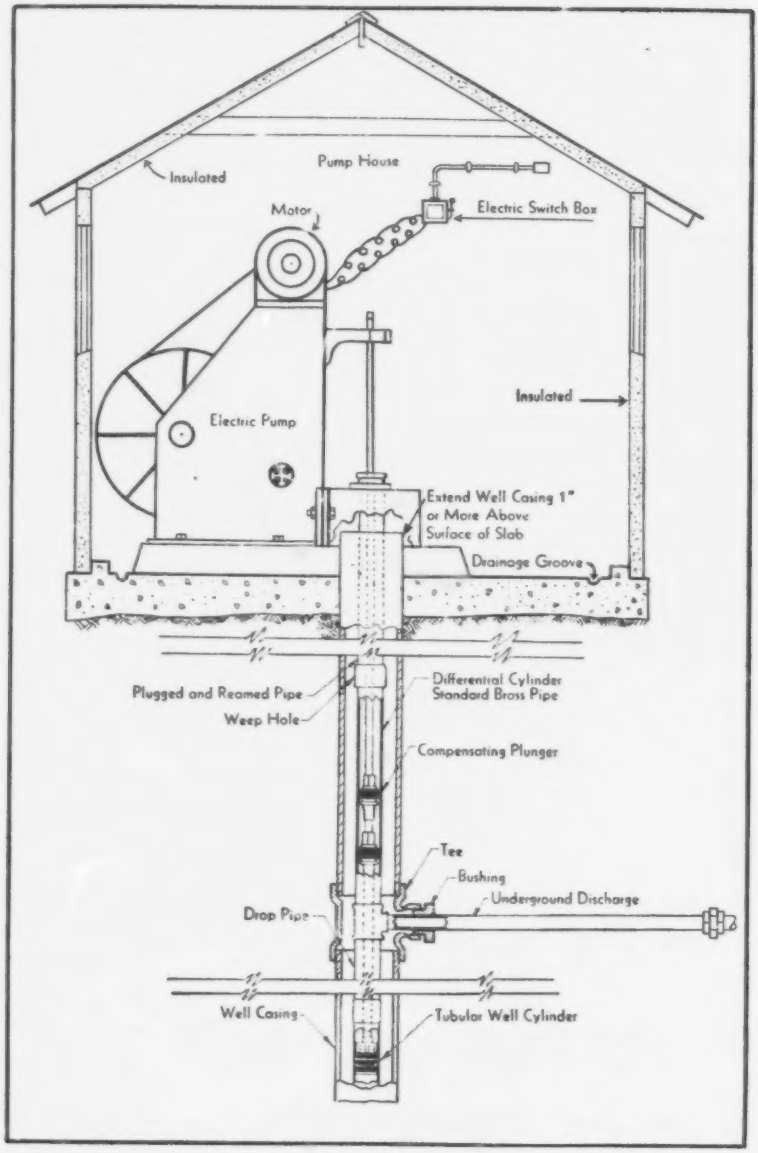

Figure 10. Typical pump installation using standard tee and underground arrangement to discharge water below frost line.

regard to the character of the water. When there is any question as to the material to be used, advice should be obtained from the State health department, State university, or consulting engineers or chemists in the waterworks field.

The pipe sizes selected should be large enough to deliver the required amount of water without excessive loss of head. The following amounts of water may be delivered with a loss of head in the pipeline of approximately 30 feet per 1,000 feet:

Pipe size: *inches*	Water delivered *gallons per minute*
1	5
1½	15
2	25
2½	50
3	80
4	160

Pipes should be laid as straight as possible in trenches with air-relief valves or hydrants located at the high points on the line. Failure to provide for the release of accumulated air in a pipeline on hilly ground may greatly reduce the capacity of the line. It is necessary that the pipeline trenches be excavated deep enough to prevent freezing in the winter. Depths of from 3 to 4 feet help to keep the water in the pipeline cool during the summer months.

Frost-proof hydrants may permit contamination to enter the water system when not properly designed or installed. Such hydrants should be provided with safe and suitable drainage from their base to prevent waste water standing around the hydrant drain cock. The drainage from the base of the hydrant should not be connected to a seepage pit subject to contamination or to a sewer. The water-supply inlet to stock-water tanks, laundry tubs, and other similar installations should be placed above the flooding level of the fixture to prevent danger of back siphonage. There should be no cross-connection, auxiliary intake, bypass, or other piping arrangement whereby unsafe water or water of questionable safety can be discharged or drawn into the domestic water-supply system. To prevent reversal of flow, care should be taken to maintain an adequate minimum pressure at all points in the piping system.

Interior piping, fittings, and accessories should, in general, conform to the minimum requirements for plumbing of the American Standard Plumbing Code, ASA–A40.7–1949.[5]

STORAGE

Suitable storage facilities for the relatively small systems considered may be constructed of concrete, steel, brick, or wood above the land

[5] Obtainable at the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York.

surface or of concrete or brick if partly or wholly below the land surface. Such storage installations should receive the same care as cistern installations in the selection of a suitable location and provision against contamination. Designs for typical manhole covers and piping installations are shown in figure 9. Such installations will assist in maintaining the water supply safe from possible contamination. Asphalt or tar for waterproofing the interior of storage units is not recommended on account of the objectionable taste imparted to the water and the possibility of undesirable chemical reaction with the materials used for treatment. Specifications covering the painting of water tanks have been prepared by the American Water Works Association. The specifications provide proper safeguards concerning the use of lead-base paints.

Surface reservoirs formed by the damming of open streams are not recommended for storage of water for human consumption. They may be used for stock watering and a fence enclosure is recommended for proper maintenance.

All tanks for storage of water for domestic supply should be completely covered and so constructed as to prevent the possibility of contamination of the tank contents by outside water or other foreign matter. Figure 9 shows several designs for manhole covers and piping connections to prevent the entrance of contaminating materials and surface drainage. Concrete and brick tanks should be made watertight by a lining of rich cement mortar. Wood tanks, generally of redwood or cypress, require no special consideration beyond the requirement for covering and the screening of openings against mosquitoes, flies, and other small insects.

Tanks for stock water should be properly constructed and partially covered to prevent cattle from getting into the tank, and the area around the tank should be sloped to drain away from the tank.

Steel pressure tanks of relatively small capacity are widely used in connection with automatic systems for individual homes. The types available are of standard construction and present no sanitation hazards. The capacity of storage tanks, other than hydropneumatic tanks, in connection with a pumped supply should be not less than 2 days' requirement and should be correspondingly greater where special conditions indicate the need. Care should be taken not to make storage tanks, cisterns, or pipelines unsafe by bringing in an emergency water supply that has been contaminated at its source or in transit.

A typical concrete reservoir with screened inlet and outlet pipes is shown in figure 11. This figure also illustrates the sanitary manhole cover which overlaps an elevated rim and prevents any drainage entering the reservoir should it be constructed where one side is at ground elevation. This type of manhole frame and cover is generally designed so that it may be locked to prevent access by unauthorized persons.

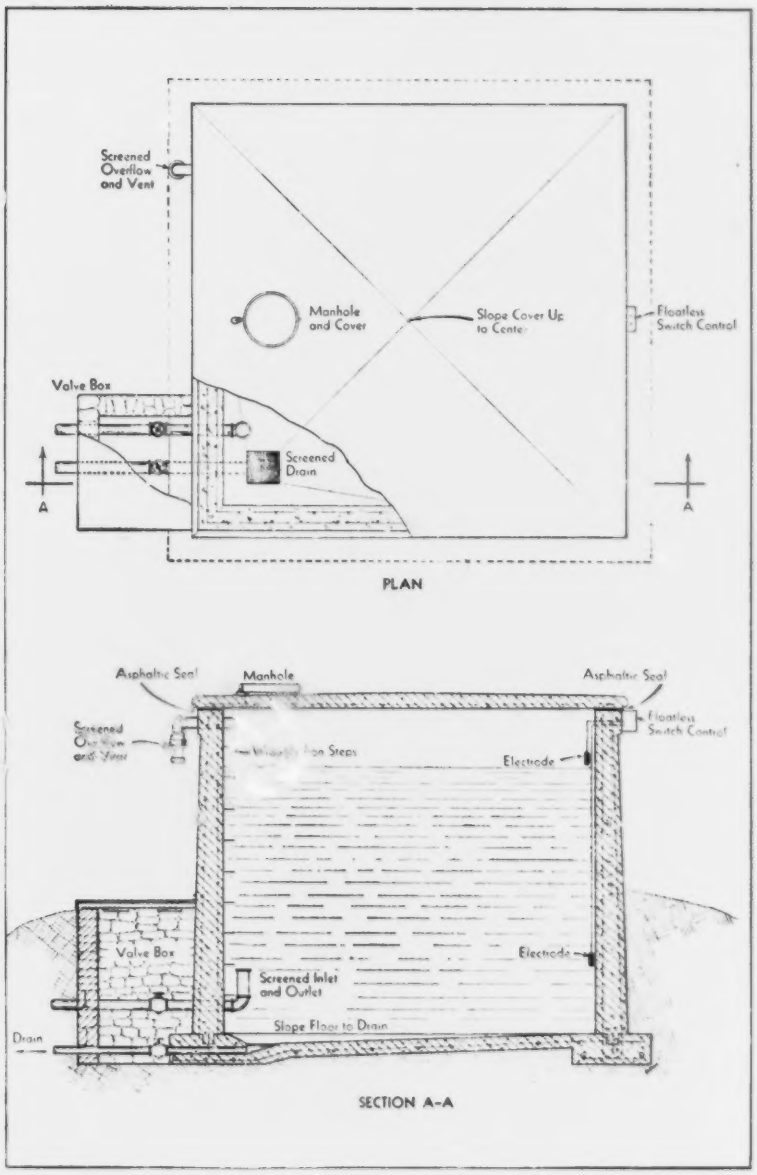

Figure 11. **Typical concrete reservoir.**

Appendix A

RECOMMENDED PROCEDURE FOR CEMENT GROUTING OF WELLS FOR SANITARY PROTECTION[6]

The annular open space on the outside of the well casing is one of the principal avenues through which undesirable water and contamination may gain access to a well. The most satisfactory way of eliminating this hazard is to fill the annular space with neat cement grout. To accomplish this satisfactorily, careful attention should be given to see that:

1. The grout mixture is properly prepared.
2. The grout material is placed in one continuous mass.
3. The grout material is placed upward from the bottom of the space to be grouted.

Neat cement grout should be a mixture of cement and water in the proportion of 1 bag of cement (94 pounds) and 5 to 5½ gallons of clean water. Whenever possible, the water content should be kept near the lower limit given. Hydrated lime to the extent of 10 percent of the volume of cement may be added to make the grout mix more fluid and thereby facilitate placement by the pumping equipment. Mixing of cement or cement and hydrated lime with the water must be thorough.

Grouting Procedure

The grout mixture must be placed in one continuous mass; hence, before starting the operation, sufficient materials should be on hand and other facilities available to accomplish its placement without interruption.

Restricted passages will result in clogging and failure to complete the grouting operation. The minimum clearance at any point, including couplings, should not be less than 1½ inches. When grouting through

[6] This information has been taken principally from a pamphlet of the Wisconsin State Board of Health, entitled "Methods of Cement Grouting for Sanitary Protection of Wells." The subject is discussed in greater detail in that publication.

the annular space, the grout pipe should not be less than 1 inch nominal diameter. As the grout moves upward, it picks up much loose material such as results from caving. Accordingly, it is desirable to waste a suitable quantity of the grout which first emerges from the drill hole.

In grouting a well so that the material will move upward, there are two general procedures that may be followed. The grout pipe may be installed within the well casing or in the annular space between the casing and drill hole if there is sufficient clearance to permit this. In the latter case, the grout pipe is installed in the annular space to within a few inches of the bottom. The grout is pumped through this pipe, discharging into the annular space, and moving upward around the casing, finally overflowing at the land surface. In 3 to 7 days the grout will be set, and the well can be completed and pumping started.

When the grout pipe is installed within the well casing, the casing should be supported a few inches above the bottom during grouting to permit grout to flow into the annular space. The well casing is fitted at the bottom with an adapter threaded to receive the grout pipe and a check valve to prevent return of grout inside of the casing. After grout appears at the surface, the casing is lowered to the bottom and the grout pipe is unscrewed immediately and raised a few inches. A suitable quantity of water should then be pumped through it, thereby flushing any remaining grout from it and the casing. The grout pipe is then removed from the well and 3 to 7 days are allowed for setting of the grout. The well is then cleared by drilling out the adapter, check valve, plug, and grout remaining within the well.

A modification of this procedure is the use of the well casing itself to convey the grout to the annular space. The casing is suspended in the drill hole and held several feet off the bottom. A spacer is inserted in the casing. The casing is then capped and connection made from it to the grout pump. The estimated quantity of grout, including a suitable allowance for filling of crevices and other voids, is then pumped into the casing. The spacer moves before the grout, in turn forcing the water in the well ahead of it. Arriving at the lower casing terminal, the spacer is forced to the bottom of the drill hole, leaving sufficient clearance to permit flow of grout into the annular space and upward through it.

After the desired amount of grout has been pumped into the casing, the cap is removed and a second spacer is inserted in the casing. The cap is then replaced and a measured volume of water, sufficient to fill all but a few feet of the casing, is pumped into it. Thus all but a small quantity of the grout is forced from the casing into the annular space. From 3 to 7 days are allowed for setting of the grout. The spacers and grout remaining in the casing and drill hole are then drilled out and the well completed.

If the annular space is to be grouted for only part of the total depth of the well, the grouting can be carried out as directed above when the well reaches the desired depth, and the well can then be drilled deeper by lowering the tools inside of the first casing. In this type of construction, where casings of various sizes telescope within each other, a seal should be placed at the level where the telescoping begins, that is, in the annular space between the two casings. The annular space for grouting between two casings should provide a clearance of at least 1½ inches, and the depth of the seal should be not less than 10 feet.

Appendix B

RECOMMENDED PROCEDURE FOR DISINFECTION OF WELLS, SPRINGS, AND APPURTENANCES

An effective and economical method of disinfecting wells, springs, and appurtenances is by the use of calcium hypochlorite (chlorinated lime) containing approximately 25 percent available chlorine. This material can be purchased at most drug stores and in large quantities at a smaller cost from chemical supply houses; a fresh supply should be used since the chemical deteriorates on exposure to the atmosphere. If commercial preparations of high-test calcium hypochlorite containing approximately 70 percent available chlorine are used, the required dosage will be about one-third the amount of chlorinated lime specified below.

Liquid capacity of wells or spring structures and the amounts of chlorinated lime required to provide a dosage of approximately 50 parts per million of available chlorine.

Capacity of well or spring in gallons	Chlorinated lime required (25% available chlorine)		Approximate volume of water, in gallons to be used in preparing chlorine solution
	Pounds	*Ounces*	
50	.....	1.5	5
100	.....	3.0	5
200	.....	6.0	5
300	.....	9.0	5
400	.....	12.0	5
500	.....	15.0	5
1,000	1	14.0	10
2,000	3	12.0	15
3,000	5	10.0	20

To the amount of chlorinated lime specified in table 1 add small quantities of water slowly and stir until a smooth, watery paste free from lumps has been formed. Add the indicated volume of water to the paste and stir thoroughly from 10 to 15 minutes prior to allowing the solution to settle. The clearer liquid containing the chlorine should be used and the inert material or lime that has settled to the bottom of the container

discarded. The solution should be prepared in a thoroughly cleaned utensil; the use of metal containers should be avoided, if possible, since they are corroded by strong chlorine solutions. If the water-bearing stratum has been contaminated, it may be necessary to force chlorinated water into it. Procedures for doing this are given below. In such cases the capacity of the well, as indicated in the accompanying table, should include the volume of water to be forced into the water-bearing stratum, or a stronger chlorine solution should be used.

Where small quantities of chlorinated lime are required and a scale is not available, the material can be measured with a spoon. A moderately heaping tablespoonful of chlorinated lime weighs approximately ½ ounce.

Dug Wells

1. After the casing or lining is completed, carry out the procedure outlined below before the cover platform is placed over the well.

(a) Remove all equipment and materials including tools, forms, platforms, etc., which will not form a permanent part of the completed structure.

(b) Wash the interior walls of the casing or lining with a strong solution of chlorinated lime (100 ppm of chlorine) using a stiff broom or brush to assure thorough cleaning.

(c) Pump the water from the well until it is perfectly clear and remove the pumping equipment that was temporarily set up for this purpose.

2. Place the cover over the well and pour the required amount of chlorinated lime solution into the well through the manhole or pipe sleeve opening just prior to inserting the pump cylinder and drop-pipe assembly. Care should be taken to distribute the chlorine solution over as much of the surface of the water as possible to obtain proper diffusion of the chemical with the well water. Diffusion of the chemical with the well water may be facilitated by running the solution into the well through a hose or pipe line as the line is being alternately raised and lowered, and this method should be followed whenever possible.

3. Wash the exterior surface of the pump cylinder and drop pipe with the chlorinated lime solution as the assembly is being lowered into the well.

4. After the pump has been set in position, pump water from the well until a strong odor of chlorine is noted.

5. Allow the chlorine solution to remain in the well for not less than 12 hours.

6. After 12 hours or more have elapsed, the well should be flushed by pumping the water to waste to remove all traces of chlorine.

Drilled, Driven, and Bored Wells

1. When the well is being tested for yield, the test pump should be operated until the well water is as clear and free from turbidity as possible.

2. After the testing equipment has been removed, pour the required amount of chlorinated lime solution into the well slowly just prior to installing the permanent pumping equipment. Diffusion of the chemical with the well water may be facilitated by running the solution into the well through a hose or pipe line as the line is being alternately raised and lowered. This method should be followed whenever possible.

3. Wash the exterior surface of the pump cylinder and drop pipe with a chlorinated lime solution as the assembly is being lowered into the well.

4. After the pump has been set in position, operate the pump until water discharged to waste has a distinct odor of chlorine. Repeat this procedure a few times at intervals of about 1 hour to assure complete circulation of the chlorine solution through the column of water in the well and the pumping equipment.

5. Allow the chlorine solution to remain in the well for not less than 12 hours.

6. After 12 hours or more have elapsed, the well should be flushed by pumping the water to waste to remove all traces of chlorine. The pump should be operated until water discharged to waste is free from the odor of chlorine.

In the case of deep wells having a high water level, it may be necessary to resort to special methods of introducing the disinfecting agent into the well so as to insure proper diffusion of chlorine throughout the well. The following method is suggested:

Place chlorinated lime or high-test granulated calcium hypochlorite in a short section of pipe capped at both ends. A number of small holes should be drilled through each cap and one of the caps fitted with an eye to facilitate attachment of a suitable cable. By lowering and raising the pipe section throughout the depth of the water, the disinfecting agent is distributed.

Flowing Wells

The water from flowing wells is generally free from contamination as soon as the well is completed or after it has been allowed to flow a short time. It is, therefore, not generally necessary to disinfect flowing wells. If, however, analyses show persistent contamination, the well should be thoroughly disinfected, for which purpose the following procedure can be followed:

Use a device such as is described in the preceding section or any other appropriate device by means of which a surplus supply of the disinfectant can be placed at or near the bottom of the well. The cable can be passed through a stuffing box at the top of the well. After the disinfectant has been placed at or near the bottom of the well, throttle down the flow sufficiently to obtain an adequate concentration of the disinfectant. When water showing adequate concentration of the disinfectant appears at the surface, close the valve completely and keep it closed for at least 12 hours.

Springs

Spring encasements should be disinfected by a procedure as nearly as possible like that used for dug wells. If the head is not sufficient to raise the water to the top of the encasement, it may be possible to shut off the flow leaving the spring and thus keep the disinfectant in the encasement during the desired period of 12 hours. If the flow cannot be shut off entirely, arrangements should be made to supply disinfectant continuously for as long a period as practicable.

Chlorine Treatment of Water-Bearing Strata

Sometimes an existing well is encountered which does not respond to the usual methods of disinfection. Usually a well like this has been contaminated by water which entered the well under sufficient head to cause a flow of water from the well into the water-bearing formation carrying the contamination with it. To reach the bacteria which have thus been carried into the water-bearing formation, it is necessary to force chlorine into the formation. This may be done in a number of ways, depending on the construction of the well. In some wells it is advisable to chlorinate the water in the well and then add a considerable volume of chlorinated water in order to force the treated water into the formation. When this procedure is followed all chlorinated water used for the purpose should have a chlorine strength of approximately 50 ppm prepared in accordance with information given in the table of this appendix. In other wells, such as the drilled well cased with standard-weight casing pipe, it is entirely practicable to chlorinate the water in the well, then cap the well and apply a head of air. By alternately applying and releasing the air, a vigorous surging effect is obtained and chlorinated water is forced into the water-bearing formation. In this procedure the chlorine strength of the treated water in the well will be reduced by dilution as it mixes with the water in the water-bearing formation. It is, therefore, advisable to double or triple the quantities of chlorine compound to be used as indicated in the table so as to have a chlorine strength of 100 to 150 ppm in the well as the surging process is started. After treating a well in this manner it is, of course, necessary to flush it to remove the excess chlorine.

Disinfection of Water-Pipe Systems[7]

General. These instructions cover the disinfection of water-pipe systems and attendant standpipes or tanks, as a preliminary to placing the system in service with water of satisfactory quality for domestic use.

These instructions are applicable to three system conditions:

(a) Disinfection of a system which has been in service with raw or polluted water, preparatory to transferring the service to treated water.

[7] Taken from Manual of Sanitary Standards and Practices of the Tennessee Valley Authority, with slight modification.

(b) Disinfection of a new system upon completion and preparatory to placing in operation with treated water or with water of satisfactory quality which does not require treatment.

(c) Disinfection of a system after completion of maintenance and repair operations.

Procedures. (a) The system, including tank or standpipe, should be thoroughly flushed with water to remove any sediment which may have collected in the system while in service with raw water.

Following flushing, the system should be filled with a disinfecting mixture of calcium hypochlorite and treated water. The mixture should consist of not less than 1.2 pounds of high-test calcium hypochlorite or approximately three times as much chlorinated lime to each 1,000 gallons of water, thus providing not less than 100 ppm of available chlorine.

If the system includes a tank or standpipe, a preliminary mixture of calcium hypochlorite and treated water should be prepared in a suitable container. If chlorinated lime is used the mixture should be allowed to stand for about 4 hours and the liquid then decanted from the container. The chlorine solution should then be delivered to the tank or standpipe, simultaneously with such quantity of additional treated water to be used in the system that the resultant mixture will contain not less than the specified 100 ppm of available chlorine. This process should be repeated until the tank or standpipe and the entire system are filled.

If no tank or standpipe is included in the system, the mixture of not less than 1.2 pounds of high-test calcium hypochlorite or the larger equivalent amount of chlorinated lime (for each 1,000 gallons of water to be treated) should be prepared in a suitable container. If chlorinated lime is used, the mixture should be allowed to stand for about 4 hours and then decanted. The solution should be injected directly into the system, the process being repeated until the system is filled.

The disinfectant should be retained in the system, and tank or standpipe, if included, for not less than 48 hours and then drained from the system and examined for residual chlorine. If no residual chlorine is found present, the process should be repeated.

Following the above, the system should be flushed with the treated water to be used in the system and may then be placed in service.

(b) The disinfectant mixture should consist of not less than 0.6 pound of high-test calcium hypochlorite or an equivalent amount of chlorinated lime, approximately 2 pounds, to each 1,000 gallons of water, providing not less than 50 ppm available chlorine.

The mixture should be injected into the system as set forth for procedure (a).

The disinfectant should be retained in the system for not less than 12 hours and then drained from the system, the system flushed with treated water and placed in service.

(c) The system or part of the system which has been affected by the maintenance or repair operations should be treated as set forth in procedure (a) with the exception that the disinfectant should be retained for not less than 12 hours.

The high-test calcium hypochlorite should contain not less than 70 percent available chlorine. The commercial products known as HTH, Perchloron, or Maxochlor, of the above percentage of available chlorine, are satisfactory.

Bacteriologic tests following disinfection. If bacteriological examination of water samples collected after disinfection indicates that the water is not safe to use, the disinfection should be repeated until tests show that water samples from that portion of the system being disinfected are satisfactory from a bacteriological standpoint. Samples collected immediately after disinfection may not be representative of the water served normally. Hence, if bacteriological samples are collected immediately after disinfection, it is desirable that the sampling be repeated several days later to check on the delivered water under normal conditions of operation and use. The water from the system should not be used for domestic and culinary purposes until the report on the bacteriological examination of water samples indicates that the water is safe for domestic use. If repeated disinfection does not give satisfactory results, all such water used for drinking or cooking purposes should be disinfected before use, or the supply abandoned for domestic use and a satisfactory supply developed.

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